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# Three Essays on Population Health and Public Health Policy

A thesis presented

by

**Xiaochuan (Sherry) Wang**

to

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# Abstract

**Chapter One: Empowered Patient or Empowered Physician: An Analysis of the Importance of the Gatekeeper in the Health Delivery System.** This paper examines the important role of the gatekeeper in the health delivery system. A simple theoretical model is developed which compares the resource allocation when physicians act as gatekeepers with the decisions taken when patients are empowered. It is shown that even when there is no asymmetry of information – and so patients and doctors are equally able to identify the appropriate therapy – that the institutional arrangement matters, and that the resource allocation will be affected by who in fact has decision-making power. Patients demand more time with physicians when they are empowered, whereas physicians want to spend more time developing their expertise when they are empowered. The reaction of physicians and patients to changes in policy instruments also differs across institutional arrangements. The analysis also draws attention to the design of the compensation scheme for physicians, and investigates the benefits of using a non-linear scheme.

**Chapter Two: Wealth, Health, and the Pursuit of Happiness.** This paper provides a theoretical framework to illuminate the relationship between income, utility maximization, and healthy choices. The analysis indicates that the choices of individuals who maximize utility are not the same as those arising were the individual to maximize wellness. In fact, rational individuals will over-eat and under-exercise relative to health-maximizing levels. Yet as individuals get wealthier, they have better health. The paper also compares different strategies for health promotion. Income redistribution may lead to a net increase in population health and in social welfare. By contrast, policies that specifically target lifestyle choices may succeed in persuading citizens to choose a health-maximizing lifestyle, but result in a net welfare loss to society. Moreover a health-maximizing fiscal policy cannot be implemented on poor individuals whose income is below a critical level.

**Chapter Three: An Empirical Investigation of Household Income and Income Policies on Obesity in Canada.** Using the master files of the Canadian Community Health Survey (CCHS), this paper examines the effect of income on obesity and individuals' body-mass index. An instrumental variable technique is employed to derive consistent estimates of this effect and to take account of the possible endogeneity between income and body weight. It is found that higher income will lead to lower body weight for women, while its effect on the body-weight outcome of men is unclear. This chapter uses the estimates of the relationship between income and body weight to simulate the impact of government income policies – like social assistance and child support – on obesity. It is shown that incomes policies may not only decrease income inequality but may also contribute to a lower incidence of obesity amongst the poorer population thus decreasing overall health care costs.

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# Contents

# Dissertation Review

This thesis investigates a number of important issues at the frontier between health economics and public economics. Around the world, public spending on health care has increased dramatically over the last two decades, and governments are facing significant challenges to meeting the funding needs of the public health-care system. There are many factors contributing to the increased demand for health-care dollars, such as the aging of the population, advances in medical technology, and new drug therapies. However, regardless of the specific channels which underlie the increased demand for health-care funding it is evident that there is a significant opportunity cost – in terms of foregone spending on income support programs, on education, on environmental protection, etc. – associated with pouring more and more dollars into the health-care system. This means that it is not only critical to ensure that resources within the health care sector itself are efficiently allocated, but also it must be certain that the effectiveness of public dollars spent on health care would not be increased were they shifted to other spending priorities. In particular, researchers concerned with the social determinants of health have underscored the importance of factors such as household income in determining health outcomes. This implies that public policies which affect the distribution of income are not only tools for redistributing welfare across the population, but also potentially effective tools for improving population health. It is therefore possible that population health might in fact be greater if public funding were taken away from the health-care sector, and redirected towards income support programs. This dissertation is concerned with both aspects of efficient resource allocation in health-care spending. It addresses how institutions affect the efficiency of resource allocation within the health-care sector, and the relationship between the distribution of income and health outcomes. The analysis developed in this thesis generates new insights into the issue of how policy makers who are responsible for population health should consider the tradeoffs between direct spending on health care versus spending on factors which strongly influence health outcomes.

The first chapter examines the important role of institutions in influencing resource allocation in the health delivery system. It focuses specifically on the role of the gatekeeper to the public health-care system in influencing overall demand for health care. At present, one of the key distinctions between publicly-funded health-care systems – such as the Canadian system – and a privately-funded system – such as the American model – is that primary care physicians act as a gatekeeper to the public health care system, whereas consumers can access specialists directly in privately-funded regimes. Some commentators have argued that it is a waste of resources to require patients to access specialist care via primary care physicians in a society where reliable sources of health information are increasingly available, and in which sophisticated expert systems will be increasingly able to assist consumers in obtaining accurate diagnoses of their health problems. In these circumstances, it may be asked whether it might be more efficient to allow patients to address themselves directly to a specialist, even in a publicly-funded system.

This chapter develops a simple theoretical model which compares resource allocation when physicians act as gatekeepers with the decisions taken when patients are empowered. It is shown that even when there is no asymmetry of information – so patients and doctors are equally able to identify the appropriate therapy – that the institutional arrangements matter, and that resource allocation will be affected by the locus of decision making power. Patients demand more time with physicians when they are empowered relative to the situation when physicians have control. In contrast, physicians want to spend more time relative to what would be chosen by patients developing their expertise when they are empowered. The reaction of physicians and patients to changes in policy instruments also differs across institutional arrangements. The analysis also provides some new insights into the optimal design of a compensation scheme for physicians, and investigates the benefits of using a scheme combing fixed and variable elements.

In Chapter 2, the focus shifts from resource allocation within the health-care sector to the broader issues of the determinants of population health. This chapter develops a theoretical framework to illustrate the relationship between income, utility maximization, and the lifestyle choices which promote health. The analysis indicates that utility-maximising individuals will generally not make the same choices as will an individual who seeks merely to maximize wellness. It is shown that a rational person who is looking for happiness, i.e., maximizing his or her utility, might make unhealthy choices from the point of view of wellness. Specifically this person will choose to overeat and under-exercise relative to what is required to maximize health. The model also predicts that wealthier individuals will have better health outcomes relative to less wealthy individuals, *ceteris paribus*.

The chapter examines the impact on social welfare and on population health of health promotion policies as well as incomes policies. It is shown that an income-redistribution policy may increase the average health status of the community. In contrast, fully subsidizing exercise is an effective way to improve the wellness of the population, but at a considerable loss of social welfare. Finally, the analysis highlights the issue of the affordability, and shows that health policy and income policy are closely linked at low levels of income – without adequate income, poor individuals simply cannot choose a healthy lifestyle.

The third chapter in this dissertation also investigates the relationship between income and health outcomes, but from an empirical perspective. It is an empirical investigation of the effect of household income on an important health indicator, namely, obesity among adult Canadians. There has been a notable increase in the prevalence of obesity in Canada. The increased prevalence of obesity is a public finance issue, since obesity is estimated to be the second most expensive disease for the health-care system to deal with, after smoking. The underlying objective of this chapter is to establish whether or not an income maintenance policy – e.g., the level of social assistance payments - may have a significant impact on health outcomes. The analysis draws upon two cycles of the master files of the Canadian Community Health Survey, which provides a rich source of data concerning individual lifestyle choices and health status.

To investigate the causal relationship between household income and body weight, this chapter employs an instrumental variables technique and uses a reduced-form model to derive consistent estimates of impact of income on body weight. It is found that higher income leads to lower body weight, and a lower probability of obesity for women. However, the effect of household income on the body weight outcome of men is unclear. Using the estimates of the relationship between income and body weight, simulations are conducted to examine the impact of government income policies – such as social assistance and child support – on obesity. Both simulation results show that incomes policies not only decrease income inequality but also contribute to a lower incidence of obesity amongst the poorest quartile of the population, and will decrease overall health-care costs. This paper therefore not only adds to the very limited literature that has investigated the relationship between income and obesity using Canadian data, but also represents the first attempt to measure the consequences of incomes policies for health outcomes and, particularly, for obesity.

# Chapter 1
# Empowered Patient or Empowered Physician: An Analysis of the Importance of the Gatekeeper in the Health Delivery System

## 1.1 Introduction

The past decade has been characterized by a significant shift in the perceived balance of power between doctors and patients. Whereas the doctor was once the undisputed authority with respect to appropriate medical treatment, it is now increasingly common for patients to track down information regarding ailments via the internet, and to be actively involved in the decision making process. Although the physician continues to play the role of the gatekeeper for accessing the resources of the health-care system, the fast growing knowledgable patient group is gradually adding more weight to the side of their power balance. It is natural to wonder how the increasing degree of empowerment of patients may influence the allocation of resources in the health care sector. For example, if patients were to play the role of gatekeeper instead, their choices might be very different from those presently made by physicians. Thus it is a worthwhile exercise to examine the differences that might be likely to emerge were greater decision-making power to be handed over to patients, and removed from physicians.

Due to technological developments, patients are presently more informed and have more medical knowledge than ever before. The internet revolution has dramatically expanded consumers' access to health information.[1] There are more than 20,000 websites devoted to health, all of which provide a flood of health information (Decter, 2000). As a group, physicians use the Internet more than do many other professionals.[2] Many health professionals are providing on-line consultation services as well. Some research predicts that Internet-based patient self-care will be the next generation of health care delivery, if the e-revolution is embraced by the health-care system (Dunn, 2003). There is also a marked trend towards self-diagnosis. In Britain, a total of 54.3 million pounds was spent on self-diagnostic products in 2002, up by 32% since 1998. Recent research also shows that over 80% of British adults feel they have to be really ill before they see a doctor, and younger patients are more likely to feel this way and intend to use a greater variety of self-diagnostics.[3]

As the gatekeepers to the public health-care system general practitioners are in a privileged position to influence overall health-care expenditures. A key mechanism for containing physician costs is the nature of the contract between the public health insurer and service providers. By far the most dominant form of payment for physician services in Canada is fee-for-service, with 89% of family physicians receiving this form of payment[4]. Physicians are paid a set fee for each service they perform. The fees are set by negotiations between provincial medical associations and provincial governments. However, it is

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1 According to Statistics Canada's Household Internet Use Survey (2003), searching for medical or health-related information was the third most popular Internet use after e-mail and general browsing. About 65% of households had at least one member who used the Internet to search for health-related information.

2 American Medical Association. General news. New AMA study shows physicians' use of Internet steadily rising. URL: http://www.ama-assn.org/ama/pub/print/article/1615-6477.html [accessed 2002 Sep 6]

3 Reuters Health News , Oct. 29, 2003.
URL: http://12.31.13.115/healthnews/reuters/20031029elin004.htm

4 Result obtained from Summer Report – Physician Workload, CFPC National Family Physician Survey 2003.

worthwhile emphasizing that one important factor in the production of health-care services – namely, the physician's expertise(effort) – is not contractible. With one production input noncontractible, and obviously controlled only by the physician herself, the choices of the empowered patient[5] and those of empowered physician will generally differ. It remains to examine what sort of contractual arrangement will lead the physician to make an appropriate investment in her expertise. In view of the increasing prevalence of self-diagnosis, and greater degree of patient involvement in determining treatment, a natural alternative to our traditional model of the 'physician as gatekeeper' would be to empower patients to access the resources of the health-care system more directly. In this paper we contrast the resource allocation when physicians are empowered and that when power is shifted to patients. The related literature is reviewed in the next section. Section 3 presents a model in which it is assumed that patients and physicians are equally knowledgeable about the appropriate treatment for a given health condition. Section 4 provides a detailed analysis of the differences in the choices made by the different parties. The purpose is to highlight the effects of institutions on the allocation of resources: we contrast outcomes when the patient and the physician occupy the position of gatekeeper in the health-care system, and present a number of interesting comparative statics results. Section 5 provides the analysis on the social planner's choice of policy instruments. The final section concludes.

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[5] In this chapter, empowered patients refer to well-informed patients who have the access to health-care resources directly. Empower patients actually play the role of gatekeeper.

## 1.2 Related Literature

A preoccupation of literature has focused on asymmetric information between the patient and the physician. The Principal-Agent approach is used to make analysis on health care provision. It has been widely recognized that there exists a trade-off between cost containment and the quality of health care (Davis *et al.*, 1989). The contractual relationship between the health provider and the insurer is therefore very important for controlling costs. Some papers have been devoted to designing an optimal compensation scheme for the health delivery system.

Over the past decades numerous attempts have been put into place to control fast growing health expenditures, of which spending on physician's service accounts for about one fifth of total costs. Ma (1994) finds that optimally designed prospective payments can implement the efficient quality and cost reduction efforts provided the health provider is compelled to accept all patients. When the provider can refuse expensive patients, implementation of the first best requires a mixture of pure prospective payment and pure cost reimbursement. Under appropriate conditions, prospective payment can implement the first best even when the provider can discriminate between patients. Ma (1997) models the interaction of cost and quality incentives when the provider is partially altruistic. The provider is assumed to maximize a weighted sum of profit and consumers' health benefits. When providers exert costly efforts to enhance quality and reduce cost, the first best outcomes can be implemented by a prospective payment scheme.

Chalkley and Malcomson (1998$a$) observe that both the NHS and US Medicare use contracts with payment based only on the number of patients treated but not on actual costs. They develop a model to consider the situation when the quality of health care is unmonitored. It is shown that in such cases providers will generally supply too low a quality of medical care, or will treat too many patients. The contracts are efficient only if it is efficient to treat all the patients wanting treatment. Chalkley and Malcomson(1998*b*) analyze contracts to reduce health costs while maintaining health-care quality when the patient cannot distinguish between different qualities of health-care services. The paper shows that the optimal contract depends on whether the provider is entirely self-interested or has some degree of concern for the patient's welfare. There are roles for block contracts, or cost and volume contracts when the provider is fully benevolent. Otherwise, some degree of cost sharing is typically optimal.

The physician's effort, or her medical expertise, is a determining factor for the quality of health-care services. In the real world, effort is not easily observed, and so is typically a noncontractible input in the production of health-care services. The relationship between the insurer and heath-care providers is similar to that between a regulator and a firm. The Averch and Johnson (1962) model has had far-reaching influence in understanding the issue of input choice in the regulation literature. Their model examines the input choices of the firm when the regulator influences the rate of return to only one of the factors of production, and shows that this distorts the investment decisions made by firms. Re-interpreting this model in a health care context, it is evident that physicians must be provided with appropriate incentives to provide health care efficiently. Ma and McGuire (1997) point out that some factors of production of health-care services are never "reported", and are thus noncontractible. They characterize an optimal insurance scheme for patients and payment method for physicians when neither the input decided by the patient (quantity) nor the input decided by the physician (effort) are contractible. It is shown that the noncontractibility of physician effort leads to an additional distortion in resource allocation if restrictions on the quantity of treatment are binding. Because of the existence of these two sources of market failure, a third-best allocation may result, which involves an undersupply of physician effort and is characterized by provider "prospective payment".

Based on this model, Léger (2000) examines the effects of quality control measures within prepayment compensation schemes. He uses a simple model with one patient, one physician, and a third party monitor to describe two contractual arrangements, one which features third-party monitoring and the other with internal monitoring. Léger's analysis predicts that the underprovison of care is less likely in the first case, and infinite fines are socially optimal with third-party monitoring. Leonard and Zivin (2001) construct a joint production model of health with two-sided asymmetric information and examine how physicians should be compensated. In their model they assume that neither the patient's nor the physician's efforts are observable. They compare effort-contingent payments and outcome-contingent payments when patient and physician effort are highly complementary. They find that outcome-contingent schemes perform better than effort-contingent ones. The reverse is true when patient and physician efforts are not highly complementary.

In addition, a number of papers have examined how the improvement of consumer information can act as a check on physicians' opportunistic behaviors (Dranove and White (1987), Rochaix (1989), Salant (1991), Wolinsky (1993)).

There is a small literature considering the full information situation. Ellis and McGuire (1990) consider a bargaining model between a physician and a representative patient. The patient's informational disadvantages are disregarded: they assume no asymmetry of information between the patient and the physician. Using this model they describe the optimal combination of insurance and reimbursement schemes that maximize consumer welfare. They conclude that the optimal payment scheme which maximizes patient's welfare will lead the physician to provide less health care than what the patient needs. Blomqvist (1991) shows that it is possible to design a system that overcomes the information asymmetry problem and leads to a pattern of health services provision that is similar to what would result if consumers had as much information as physicians do. Under a fee-for-service payment contract from the insurer and under asymmetric information, the supply of health care is always greater than the efficient level. Alternative contractual arrangements, such as an HMO contract, cannot overcome all the agency problems despite some improvements in efficiency. Some additional instruments, such as a performance guarantee or liability rule, are needed to overcome the double agency problem.

Most of the papers mentioned previously are concerned with finding an optimal payment scheme to offset the negative effect of information asymmetry and noncontractibility of production inputs. Although physician compensation schemes are very important for controlling health-care costs, this is not the whole story. This literature overlooks the fact that it is the physician who determines the nature of the access to the health care system. In the model presented in the next section we assume information symmetry between the patient and the physician, and so we can truly isolate the gatekeeper effect.[6] The main contribution of this paper is to examine the impact of a shift in power from physicians to patients in the health-care delivery system.

## 1.3 Model

We propose a simple model in which there is a representative patient, a representative physician, and a social planner. The physician provides health care to the patient, including both diagnosis and therapy, and is paid on working hours. We assume that health-care services are provided in a publicly funded system. Health-care services are provided free of charge, and are financed by a linear proportional tax on income. The social planner is responsible for balancing the health-care budget and for general equity objectives with respect to the distribution of income. It is also assumed that the production of health care services depends both on the physician's time input and her specific medical expertise. The time input is the physician's contact time with the patient, providing a diagnosis, undertaking medical tests, and prescribing medicines. The productivity of physician time spent with patients depends on the physician's degree of expertise, or human capital. Physicians may spend time reading medical journals, and studying other case histories. Such additional working hours are not paid. These investments in human capital could also be interpreted as the physician's effort, or the quality of the heath care. These hours are assumed to be noncontractible.

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6 Under the assumption that patients are as knowledgeable as physicians, any difference in health resources allocation will be attributed only to the different institutional arrangement, i.e., which party actually plays the role of gatekeeper.

Physicians are paid on working hours. An important assumption is that the compensation scheme is non-linear: total compensation is equal to $wt + T$, where $w$ is the wage rate, $t$ denotes the contact time, and $T$ is a lump-sum tax (or transfer). We assume the wage rate is viewed as exogenous by both the physician and the patient. It can be thought of as determined by negotiations between the government and the medical association at an earlier time. $T$ might possibly be interpreted as the present-value to the physician of subsidized medical education. One important consequence of introducing the possibility of a lump-sum tax (or transfer) is that this provides an additional instrument to the planner with which to redistribute income, and therefore social welfare. Without $T$ the only way for the social planner to redistribute income is by sending patients to visit the physician more or less frequently. In effect, equity objectives may lead the social planner to send healthy people to the doctor for a 'wellness visit', or oblige sick individuals to forego medical care, because this would overstrain the health care system. By introducing $T$ a much-needed element of flexibility is introduced into the resource allocation decision process. Total payments to physicians (i.e., the payments for services provided, plus any eventual transfer) are financed by a linear proportional income tax on the patient. The patient views the proportional tax rate as exogenous, and thus in fact treats this as a lump-sum tax.[7]

The patient's utility depends on his consumption of the private good, $X$, and his health status, $H$, given his income endowment $I_0$ and initial health status $H_0$. The patient's health status $H$ depends on his initial health status $H_0$ and medical treatment $M$, which

[7] We present a two-stage model in which patients and physician make decision in the second stage. Thus the policy instruments (tax rate $\tau$ and wage rate $w$) are exogenous for both of them. Patients are assumed not to see through the public sector budget constraint, and the relaxation of this assumption is an interesting direction for future research.

is a strictly concave function $g(t, K)$, where $t$ denotes the physician's contact time with the patient, and $K$ denotes the physician's level of expertise. We assume that utility is increasing in $X$ and $H$, the health care production function is increasing in $t$ and $K$, and that health status is increasing in $H_0$ and $M$.

The physician is endowed with 1 unit of time, which must be allocated between contact visits with patients, investing in expertise, and leisure $(1 - t - K)$. Time spent with patients is remunerated at wage rate $w$, whereas time invested in acquiring additional expertise is not remunerated. The physician also cares about improvements to the patient's health status $(H - H_0)$.

The game consists of two stages. In stage one, the Social Planner chooses policy instruments–specifically, the wage rate $w$ for the physician and lump-sum transfer $T$. In stage two, either the physician or the patient, depending on who is the empowered party, chooses $t$, the contact time, and the physician always chooses the level of expertise to acquire. In the case that the patient is empowered, the physician and the patient will make their choice simultaneously.

So as to be able to focus on the consequences of institutional design, we abstract from the typical concerns created by the informational asymmetry that generally exists between a patient and a physician. Instead, we assume that both the physician and the patient understand the production technology for health-care services. However, we assume that only contact time, $t$, can be contracted upon: physicians always retain control of their investment in the acquisition of expertise.

## 1.4 The Second Stage Analysis

This section examines the resource allocation in the second stage, in which the empowered agent chooses contact time $t$ and/or expertise investment $K$, given the wage rate $w$ and money transfer $T$. We first consider the case of efficient allocation, and then compare it to the results obtained when either the patient or the physician is empowered.

### 1.4.1 Efficient Resource Allocation in Stage Two

We now characterize efficient resource allocation in the second stage of the game when the social planner has both full information and full control over both physician and patient decision-making. The planner is assumed to maximize a Benthamite social welfare function, and so simply maximizes $U_1 + U_{2.}$ So as to facilitate comparisons with subsequent analysis, we assume that the planner pays for physician contact time at wage rate $w$. All payments to the physician must be financed by a proportional tax on patient income. Note that, since $w$ is treated as exogenous, the solution to this problem is not a true 'first best', and merely characterizes efficient resource allocation for given $w$.

The problem for the social planner can be expressed as:

$$\underset{t,K,T}{Max}\; U_1\left(I_0 - wt - T,\ H;\ H_0, I_0\right) + U_2\left(I,\ L,\ \Delta H\right)$$

$$\begin{aligned} \text{subject to } H &= f\left(H_{0,}\, g\left(t, K\right)\right) && (1.1a) \\ I &= wt + T && (1.1b) \\ L &= 1 - t - K && (1.1c) \end{aligned}$$

$$\Delta H = f(H_0, g(t, K)) - H_0 \tag{1.1d}$$

where (1.1a) describes the production technology for health, (1.1b) the income of the physician, (1.1c) the leisure consumed by the physician, and (1.1d) the change in the patient's health status. It is then straightforward to show that, at an interior solution, the first-order conditions obtained from the planner's optimization problem are:

$$\frac{\partial \mathcal{L}}{\partial t} = \frac{\partial U_1}{\partial X}(-w) + \frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t} + \frac{\partial U_2}{\partial I}w - \frac{\partial U_2}{\partial L} + \frac{\partial U_2}{\partial \Delta H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t} = 0 \tag{1.2}$$

$$\frac{\partial \mathcal{L}}{\partial K} = \frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial K} - \frac{\partial U_2}{\partial L} + \frac{\partial U_2}{\partial \Delta H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial K} = 0 \tag{1.3}$$

$$\frac{\partial \mathcal{L}}{\partial T} = -\frac{\partial U_1}{\partial X} + \frac{\partial U_2}{\partial I} = 0 \tag{1.4}$$

We denote the solution to the planner's problem as ($t^*$, $K^*$, $T^*$). Observe that equation (1.2) requires that physician time be allocated so as to equalize the social marginal benefit with the social marginal cost of additional contact time. The marginal social benefit of increased contact time comprises three elements: the benefit to the patient and to the physician of an improvement in the patient's health status, plus the marginal benefit to the physician of increased income. In contrast, the marginal social cost of increased patient visits is comprised of the marginal disutility to the patient of reduced income, and the marginal disutility to the physician of reduced leisure. Equation (1.3) indicates that physician time invested in the acquisition of human capital should equate the marginal private benefit of increased productivity during contact hours (direct benefit to the patient and indirect benefit to the physician of seeing improved patient health) with the marginal cost of decreased leisure. Equation (1.4) indicates that the planner will use the lump-sum transfer to equate the marginal utility of income between the physician and the patient.

### 1.4.2 Resource Allocation With Empowered Patients

Now consider the problem of resource allocation when the patient has as much information about his health, and about the appropriate course of treatment for any medical ailment, as does the physician. We consider a situation in which the patient can effectively command health-care resources, and so can choose how much time the physician will spend treating him. When the patient is given the capacity to command health-care resources, his problem is to choose $t$ so as to maximize the utility from the consumption of after-tax income $(1-\tau) I_0$ and from health status $H$. We assume the overall policy environment has been determined by the social planner so that the patient can contract $t$, the physician's working time. However he cannot contract over $K$, which is unobservable, and decided by the physician who is simultaneously solving her own utility maximizing problem. Although medical care is free (financed by a linear proportional income tax on patient income), the patient cannot coerce the physician to provide services if the physician's utility falls below $\underline{U_2}$, which is interpreted as the physician's reservation utility; this therefore acts as a constraint on the patient's demand for medical services. (We interpret this constraint as representing the utility that the physician could obtain in seeking employment in another jurisdiction.) The maximization problem of the patient is:

$$\underset{t,\lambda}{Max} \quad U_1\left(\left(1-\tau\right) I_0, H; H_0, I_0\right)$$

$$\begin{aligned} \text{subject to } H &= f\left(H_0, g\left(t, K\right)\right) \\ \underline{U_2} &\leq U_2\left(I, L, \Delta H\right) \end{aligned}$$

The first order conditions are derived as:

$$\frac{\partial \mathcal{L}_{PA}}{\partial t} = \frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t} + \lambda\left(\frac{\partial U_2}{\partial I}w - \frac{\partial U_2}{\partial L} + \frac{\partial U_2}{\partial \Delta H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t}\right) = 0 \tag{1.5}$$

$$\frac{\partial \mathcal{L}_{PA}}{\partial \lambda} = U_2\left(wt + T, 1 - t - K,\ f\left(H_0, g\left(t\right)\right) - H_0\right) - \underline{U_2} \geq 0 \tag{1.6}$$

Simultaneously, the physician chooses $K$ to maximize her own utility.

$$\underset{K}{Max}\, U_2\left(wt + T,\ 1 - t - K,\ f\left(H_0, g\left(t, K\right)\right) - H_0\right)$$

It is worthwhile to recall here that the patient has control over the amount of time devoted by the physician to patient care. Thus, the physician solves a simple utility maximization problem in which the only choice is her investment in $K$. At a solution to this optimization problem, it must be true that :

$$\frac{\partial U_2^{PA}}{\partial K} = -\frac{\partial U_2}{\partial L} + \frac{\partial U_2}{\partial \Delta H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial K} = 0 \tag{1.7}$$

The system of equations (1.5)–(1.7) implicitly determine the optimal values of $\widehat{t}^{PA}(\tau, T)$, $\widehat{\lambda}^{PA}(\tau, T)$, and $\hat{K}^{PA}(\tau, T)$. Equation (1.5) shows that the patient will contract $t$ at a level that equalizes the marginal private benefits from physician contact with the marginal cost of physician's time. The patient will improve his health through his contact with the physician, while spending too much time in this regard may violate the physician's reservation utility constraint and will not be allowed. Equation (1.7) reveals that the physician will invest time in the acquisition of human capital such that the marginal private benefit of doing so – i.e., improved patient health – is equated to her marginal cost of decreased leisure. Here it is interesting to highlight the two differences with respect to the choice of $t$ between the empowered patient and the planner, determined by equation (1.2) and equation (1.5) respectively: first, because the tax rate is exogenous, the patient does not consider the marginal income effect of his decision with respect to choice of $t$; and second, because the patient is constrained to ensure that the physician achieves her reservation utility, the first-order condition for the patient includes the Lagrangian multiplier $\lambda$, which represents the level of utility that the patient is willing to give up to relax the physician's reservation utility by one unit. We fully expect $\lambda$ to be positive and less than one given that a value of one would mean that the patient values relaxing the physician's reservation utility constraint by the same amount as the physician – which is highly unlikely. By comparing equation (1.3) to equation(1.7) we note that the one difference regarding the choice of $K$ by the social planner and the physician is that the latter does not take into account the impact of $K$ on the utility of the patient. She only benefits from the additional human capital investment through the improved health status of the patient.

### 1.4.3 Resource Allocation with Empowered Physicians

In the real world, patients do not typically access the system's resources directly in a publicly-funded health-care system. Instead the physician acts as a gatekeeper, authorizing and regulating the patient's access to medical services. It is the physician who decides how long the patient needs her care as well as which therapies should be used. The physician decides on how much time to spend with the patient, and how much time to allocate to developing her own skills and expertise. The physician's choice of $t$ and $K$ is, of course, influenced by the broader policy environment, and the physician, of course, must offer a quality of service that attracts patients (or satisfies a regulator's requirement). We capture this feature of the physician's decision-making problem by requiring that the physician ensure that patients obtain a minimum level of utility, $\underline{U_1}$, interpreted as the reservation utility of the patient. Also the overall environment has been determined by the social planner so that the physician is now in power. The physician's optimization problem can be expressed as:

$$\begin{array}{c} Max \\ \beta, t, K \end{array} \; U_2\left(I, L, \Delta H\right)$$

$$\begin{aligned} \text{subject to } I &= wt + T \\ L &= 1 - t - K \\ \Delta H &= f\left(H_0, g\left(t, K\right)\right) - H_0 \\ \underline{U_1} &\leq U_1\left[\left(1-\tau\right) I_0,\ f\left(H_{0,}\ g\left(t, K\right)\right)\right] \end{aligned}$$

The first order conditions can be expressed as:

$$\frac{\partial \mathcal{L}_{PH}}{\partial t} = \frac{\partial U_2}{\partial I} w - \frac{\partial U_2}{\partial L} + \frac{\partial U_2}{\partial \Delta H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t} + \beta\left(\frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t}\right) = 0 \tag{1.8}$$

$$\frac{\partial \mathcal{L}_{PH}}{\partial \beta} = U_1\left(\ \left(1-\tau\right) I_0,\ f\left(H_{0,}\ g\left(t, K\right)\right)\ \right) - \underline{U_1} \geq 0 \tag{1.9}$$

$$\frac{\partial \mathcal{L}_{PH}}{\partial K} = -\frac{\partial U_2}{\partial L} + \frac{\partial U_2}{\partial \Delta H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial K} + \beta\left(\frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial K}\right) = 0 \tag{1.10}$$

Solving equations (1.8) to (1.10) yield $\tilde{t}^{PH}(\tau, T), \tilde{K}^{PH}(\tau, T)$,and $\tilde{\beta}^{PH}(\tau, T)$,which denote the outcome of the resource allocation problem when the physician has decision-making power. Equation (1.8) reveals that the marginal private benefit of an additional contact hour with the patient – comprised of its marginal effect on physician income, the marginal benefit to the physician of the increased patient's health, and the marginal benefit to the physician of relaxing the reservation utility constraint – must be equal to the marginal cost of the loss of an additional hour of leisure. Equation (1.10) shows that the empowered physician's investment of time in acquiring additional expertise equates the marginal disutility of foregone leisure with the marginal benefit to the physician of the increased health of the patient, and of the relaxation of the reservation utility constraint. The comparison between equation (1.8) and equation (1.2) shows that the physician does not account for the patient's marginal utility of income associated with changes in $t$, given the tax rate is exogenous for the patient. However if we look at expressions of (1.3) and (1.10) we see that the only difference between the case when the social planner chooses $K$ versus the physician comes from the Lagrangian multiplier, $\beta$.

### 1.4.4 Why Institutions Matter: Resource Allocation and Empowerment

In this section we compare and contrast resource allocation in the second stage under the two institutional arrangements described above. We show that even when there is no asymmetry of information – and so patients and doctors are equally able to identify the appropriate therapy for a given health condition – the institutional arrangements matter, and that resource allocation will be affected by who in fact has decision-making power. These differences in outcomes are ultimately attributable to the fact that whereas health care is produced using both $t$ and $K$, the remuneration of the physician depends only on $t$.

We start by comparing the determination of physician contact time, given fixed $K$. Recall from the description of the physician and patient's optimization problems above:

$$\frac{\partial \mathcal{L}_{PA}}{\partial t} = \frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t} + \lambda\left(\frac{\partial U_2}{\partial I}w - \frac{\partial U_2}{\partial L} + \frac{\partial U_2}{\partial \Delta H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t}\right) \tag{1.5}$$

$$\frac{\partial \mathcal{L}_{PH}}{\partial t} = \frac{\partial U_2}{\partial I}w - \frac{\partial U_2}{\partial L} + \frac{\partial U_2}{\partial \Delta H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t} + \beta\left(\frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t}\right) \tag{1.8}$$

Obviously, if $\beta = \lambda = 1$, then both the patient and physician will choose the same $t$. However, in general we would expect their choices to differ. In particular, since both $\beta$ and $\lambda$ are positive, then at a solution to either the patient or physician's optimization problem it must be true that $\frac{\partial U_1}{\partial t} = \frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t} > 0$ and so $\frac{\partial U_2}{\partial t} = \frac{\partial U_2}{\partial I}w - \frac{\partial U_2}{\partial L} + \frac{\partial U_2}{\partial \Delta H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t} < 0$. In general, however, we cannot say that $\widehat{t}^{PA}(\tau, T; K) \gtrless \tilde{t}^{PH}(\tau, T; K)$. To get more insight into the differences between the patient's choice and the physician's choice of $t$, we conduct the following thought experiment: holding $K$ constant across the two institutional environments, we evaluate the first-order condition for the physician's choice at the level of $t$ which solves the first-order condition for the patient, i.e., we substitute $\widehat{t}_{PA}(\tau, T; K)$ into equation (1.8) and obtain

$$\frac{\partial \mathcal{L}_{PH}}{\partial t}|_{t=\widehat{t}^{PA}, K=\bar{K}} = (1 - \lambda\beta)\frac{\partial U_2}{\partial t}. \tag{1.11}$$

Observe that since $\frac{\partial U_2}{\partial t} < 0$ the sign of this expression depends on $\lambda\beta$. It is reasonable to argue that $\lambda\beta < 1$, since if this were not the case then the patient (or physician) would put more weight on the other party's utility than on their own well-being. Thus the following result is deduced: holding $K$ constant across the two environments, that $t^{PA} > t^{PH}$.[8]

We now conduct a similar thought experiment with respect to $K$. Holding $t$ constant, we substitute $\hat{K}^{PA}$ – the amount of time invested in professional development by the physician when the patient is empowered - into equation (1.10 ) and obtain that:

$$\frac{\partial \mathcal{L}_{PH}}{\partial K}|_{K=K^{PA}, t=\bar{t}} = \beta\frac{\partial U_1}{\partial K} \tag{1.12}$$

[8] $t^{PA}$ and $t^{PH}$ is the contact time that will be chosen when patient has control and when the physician has control respectively; $t^{Social}$ is the contact time when the social planner has the control. $K^{PA}$, $K^{PH}$, $K^{Social}$ are the expertise investment time chosen by the physician when patient, physician, or the social planner has the control respectively.

Clearly, since $\frac{\partial U_1}{\partial K} > 0$, it must be true that $K^{PA} < K^{PH}$ when $t$ is held constant across institutional environments. Given that it is the physician who actually takes the decision about how much $K$ to invest under both scenarios, and given that we are holding $t$ constant, it is intriguing to observe that the decision differs depending on the institutional environment – the physician invests less in acquiring expertise when the patient is empowered. This is explained by the fact that the empowered physician could increase her utility by trading off higher expertise with leisure. In contrast, if the contact time is decided by the empowered patient, it must be the case that the marginal utility associated with an additional unit of $K$ is less than the marginal utility of a foregone unit of leisure.

Using this same technique, we can show that, *ceteris paribus*,

$$t^{PH} < t^{PA}, \; t^{Social} < t^{PA}$$

and

$$K^{PA} < K^{PH} < K^{Social}$$

These results indicate that the choice of working time $t$ and investments in the acquisition of human capital or expertise, $K$, generally differ depending on which party is empowered to access resources.[9] Additionally, regardless of whether it is the patient or the physician who has control over this access, their choices are not socially optimal; this is not simply due to

[9] We cannot say that $t^{PH} \gtrless t^{Social}$. Holding $K$ constant, we evaluate the first-order condition of the social planner's choice at the level of $\tilde{t}_{PH}$, i.e., we substitute $\tilde{t}_{PH}$ into equation (1.3), and obtain:

$$\frac{\partial \pounds}{\partial t}|_{t=\tilde{t}^{PH}} = \frac{\partial U_1}{\partial I_0}(-w) + \frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t}(1-\beta)$$

Only if $\beta$ is very close to 0 is it possible to get $t^{Social} > t^{PH}$, otherwise $t^{Social} < t^{PH}$.

a lack of information about what therapies might be appropriate, but is entirely driven by the incentive structure.

For any given investment in expertise of the physician, the empowered patient would choose a longer period of contact time than if the physician plays the role of gatekeeper. That is, the patient cares more about the quantity of the medical service than the physician does. Moreover for any given level of medical expertise, the empowered patient will demand more contact time with the physician than is socially optimal.

Given the same level of the physician's working hours, $t$, the level of $K$ is also different when different parties have the control, though it is always the physician who makes the choice. The fact that $K^{PH}$ is unambiguously smaller than $K^{Social}$ means that, for any given $t$, physicians will tend to underinvest in expertise, lowering the quality of health care provided relative to the social optimum. However the amount of $K$ chosen by the physician when she has control is higher than that chosen by the patient, suggesting that the health-care system may perform better when the physician has control as compared to an institutional environment in which patients are empowered.

Observe that the results obtained from the model are consistent with many of the complaints expressed by both patients and doctors in publicly-funded health systems.[10] The expressed frustration of patients at the shortage of doctors, and the complaints of doctors that there is not enough time for research are not necessarily indicative of an underfunded

[10] On the one hand, some patients protested that they were being rushed through their medical visit. (Kelner, M.J. and Wellman, B. "The therapeutic relationships of older adults: comparing medical and alternative patients", *Health and Canadian Society*, Vol. 6(1):87-109, 2000). On the other hand, time constraints seem to be a crucial factor preventing particularly rural physicians from continuing medical education (*Report of Lucy C. Dobbin*, Report submitted to British Columbia Ministry of Health, 1998).

health-care system per se, but are almost inevitable in any publicly-funded health-care system, since the preferred outcomes of patients and of doctors will generally differ.

### 1.4.5 Comparative Statics

A comparative static exercise is conducted so as to answer the question that how the time choices, $t$ and $K$, of a empowered agent respond to a change in policy instruments. We focus on the wage rate for the physician, the lump-sum money transfer to the physician, and the reservation utility of the other agent. The comparative static results show how the social planner's action would influence the choices of the empowered agent under different institutional environments. We assume that both the patient's and the physician's utility functions are additively separable, that is, the cross partial effects are zero. The scenario when patients are empowered is firstly discussed and then the scenario when physicians are the gatekeepers.

**Empowered Patients**

For the situation where the patient has control, totally differentiate equations (1.5), (1.6), and (1.7) to obtain:

$$\begin{aligned} S\, d_t \; + Q\, d_K &= 0 \\ R\, d_\lambda + M\, d_t \; + N\, d_K &= -\lambda U_{II} w dT - (\lambda U_{II}\, wt + \lambda U_I)\, dw \\ W\, d_t \; + Y\, d_K &= d_{\underline{U_2}} - U_I d_T - U_I\, t\, dw \end{aligned}$$

where

$$S = U_{LL} + U_{\Delta H \Delta H} \left(f_g\right)^2 \left(g_t\right) \left(g_K\right) + U_{\Delta H} \left(f_{gg}\right) \left(g_t\right) \left(g_K\right) + U_{\Delta H} \left(f_g\right) \left(g_{tK}\right)$$

$$
\begin{aligned}
Q &= U_{LL} + U_{\Delta H \Delta H} (f_g)^2 (g_K)^2 + U_{\Delta H} (f_{gg}) (g_K)^2 + U_{\Delta H} (f_g) (g_{KK}) \\
R &= W = U_I w - U_L + U_{\Delta H} (f_g) (g_t) \\
M &= U_{HH} (f_g)^2 (g_t)^2 + U_H (f_{gg}) (g_t)^2 + U_H (f_g) (g_{tt}) + \lambda U_{II} w^2 + \lambda U_{LL} \\
&\quad + \lambda U_{\Delta H \Delta H} (f_g)^2 (g_t)^2 + \lambda U_{\Delta H} (f_{gg}) (g_t)^2 + \lambda U_{\Delta H} (f_g) (g_{tt}) \\
N &= U_{HH} (f_g)^2 (g_t) (g_K) + U_H (f_{gg}) (g_t) (g_K) + U_H (f_g) (g_{tK}) + \lambda U_{LL} \\
&\quad + \lambda U_{\Delta H \Delta H} (f_g)^2 (g_t) (g_K) + \lambda U_{\Delta H} (f_{gg}) (g_t) (g_K) + \lambda U_{\Delta H} (f_g) (g_{tK}) \\
Y &= -U_L + U_{\Delta H} (f_g) (g_K)
\end{aligned}
$$

The assumption of concavity of the utility functions and health production function enables us to determine that $Q < 0$, and from equation (1.7) we know that $Y = 0$. Also from expressions (1.5) and (1.8) we obtain that $R = W < 0$. Rewriting this system in the form of a matrix:

$$
\begin{pmatrix} 0 & S & Q \\ R & M & N \\ 0 & R & 0 \end{pmatrix} * \begin{pmatrix} d\lambda \\ dt \\ dK \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & -\lambda U_{II} w & -\lambda U_{II} wt - \lambda U_I \\ 1 & -U_I & -U_I t \end{pmatrix} * \begin{pmatrix} d_{\underline{U_2}} \\ dT \\ dw \end{pmatrix}
$$

Again we are interested in $t$ and $K$, and we want to examine how these variables change with changes in the policy instruments. Beginning, first, with changes in the physician's reservation utility, and using Cramer's Rule it is shown:

$$
\frac{dt}{d_{\underline{U_2}}} = \frac{\begin{vmatrix} 0 & 0 & Q \\ R & 0 & N \\ 0 & 1 & 0 \end{vmatrix}}{R^2 Q} = \frac{RQ}{R^2 Q} = \frac{1}{R} < 0 \tag{1.13}
$$

$$
\frac{dK}{d_{\underline{U_2}}} = \frac{\begin{vmatrix} 0 & S & 0 \\ R & M & 0 \\ 0 & R & 1 \end{vmatrix}}{R^2 Q} = \frac{-RS}{R^2 Q} = SIGN(-S) \tag{1.14}
$$

The changes in $T$, the money transfer to the physician, will influence the choice variables in the following ways:

$$\frac{dt}{dT} = \frac{\begin{vmatrix} 0 & 0 & Q \\ R & -\lambda U_{II}w & N \\ 0 & -U_I & Y \end{vmatrix}}{R^2Q} = \frac{-RQU_I}{R^2Q} = -\frac{U_I}{R} > 0 \tag{1.15}$$

$$\frac{dK}{dT} = \frac{\begin{vmatrix} 0 & S & 0 \\ R & M & -\lambda U_{II}w \\ 0 & R & -U_I \end{vmatrix}}{R^2Q} = \frac{U_ISR}{R^2Q} = SIGN(S) \tag{1.16}$$

When the patient has control, an increase in the transfer payment to physicians will lead the patient to demand longer contact time $t$ shown by equation (1.15), while an increase in the physician's reservation utility will lead him to the opposite shown by equation (1.13). The fact that these two instruments have the opposite effect should not be surprising as the former relaxes the constraint for the patient while the latter makes it become stricter. As the reservation utility increases, which indicates more attraction for the physician to seek employment opportunity elsewhere, individuals will demand less service as manifested by a decrease in clinical time. However, if the physician's transfer payment, $T$, increases then the patient will demand more contact time. Similarly, changes in these two policy instruments will have the opposite impact on the choice of $K$ by the physician under the empowered patient environment. The actual impact on $K$ of changes in $T$ and $\underline{U_2}$ depend upon the sign of $S$ – which can only be determined for the case where $t$ and $K$ are substitutes. If $t$ and $K$ are substitutes ($g_{tK} < 0$) then $S < 0$, and we have that $\frac{dK}{d\underline{U_2}} > 0$, and $\frac{dK}{dT} < 0$. Assuming that $t$ and $K$ are substitutes, an increase in the physician's reservation utility will lead the physician to choose a higher level of $K$, while an increase in the physician's transfer payment would lead her to choose a lower level of $K$. If, instead, $t$ and $K$ are complements, then we cannot say anything about which policy instrument will lead to higher level of $K$, although we can conclude that they will have opposing influences on $K$.

Similarly we get

$$\frac{dt}{dw} = \frac{-RQU_I}{R^2Q}t = -\frac{U_I}{R}t > 0 \tag{1.17}$$

$$\frac{dK}{dw} = \frac{U_I SR}{R^2Q}t = SIGN(S) \tag{1.18}$$

Under the scenario when the patient is the gatekeeper, the two policy instruments for income redistribution on time, $w$ and $T$, will have the same effect, as an increase in any of them will relax the constraint of the patient. Moreover as $w$ and $T$ enter the empowered patient model always in a pair, the magnitude of their effects are the same in the value as well.

**Empowered Physicians**

We now turn to the environment where the physicians are the gatekeepers in the medical service delivery system. Totally differentiating (1.8), (1.9), and (1.10) gives the following equations:

$$\begin{aligned} C'H\, d_t + H\, d_K &= d_{\underline{U}_1} + U_{I_0} dT + U_{I_0} t dw \\ C d_\beta + A\, d_t + B\, d_K &= -U_{II} w dT - (U_{II} w + U_I)\, dw \\ H\, d_\beta + F\, d_t + G\, d_K &= 0 \end{aligned}$$

where

$$C = U_H\, f_g\, g_t$$

$$\begin{aligned}
C' &= U_{I_0}(-w) + U_H\, f_g\, g_t \\
H &= U_H\, f_g\, g_K \\
A &= \frac{\partial^2 L^{PH}}{\partial t^2} = U_{II}w^2 + U_{LL} + U_{\Delta H\Delta H}(f_g)^2(g_t)^2 + U_{\Delta H}\,(f_{gg})(g_t)^2 \\
&\quad + U_{\Delta H}(f_g)(g_{tt}) + \beta U_{HH}(f_g)^2(g_t)^2 + \beta U_H\, f_{gg}(g_t)^2 + \beta U_H(f_g)(g_{tt}) \\
B &= F = \frac{\partial^2 L^{PH}}{\partial t\,\partial K} = U_{LL} + U_{\Delta H\Delta H}(f_g)^2\, g_t\, g_K + U_{\Delta H}(f_{gg})\, g_t\, g_K \\
&\quad + U_{\Delta H}(f_g)(g_{tK}) + \beta U_{HH}\,(f_g)^2\, g_t\, g_K + \beta U_H(f_{gg})\, g_t\, g_K + \beta U_H\,(f_g)\, g_{tK} \\
G &= \frac{\partial^2 L^{PH}}{\partial K^2} = U_{LL} + U_{\Delta H\Delta H}(f_g)^2(g_K)^2 + U_{\Delta H}(f_{gg})(g_K)^2 + U_{\Delta H}(f_g)(g_{KK}) \\
&\quad + \beta U_{HH}\,(f_g)^2(g_K)^2 + \beta U_H(f_{gg})(g_K)^2 + \beta U_H\,(f_g)\, g_{KK}
\end{aligned}$$

Given that $U_H > 0$, $f_g > 0$, $g_t > 0$, and $g_K > 0$, we have $C > 0$ and $H > 0$.

We once again rewrite the above equations into matrix form:

$$\begin{pmatrix} 0 & C' & H \\ C & A & B \\ H & F & G \end{pmatrix} * \begin{pmatrix} d_\beta \\ dt \\ dK \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -U_{II}w & -U_{II}wt - U_I \\ 0 & U_{I_0} & U_{I_0}t \end{pmatrix} * \begin{pmatrix} d_{\underline{U}_1} \\ dT \\ dw \end{pmatrix}$$

In order to achieve a maximum, the second-order conditions imply that the bordered Hessian of the physician's problem has a positive determinant. That is:

$$\begin{vmatrix} 0 & C & H \\ C & A & B \\ H & F & G \end{vmatrix} = CFH + CBH - AH^2 - C^2G > 0.$$

Thus it can be shown that the matrix above has a positive determinant as well as $C > C'$. Then we get the signs of the comparative statics for $t$ and $K$ as follows:

$$\begin{aligned}
&\mathrm{Si}\,gn\left(\frac{dt}{d_{\underline{U}_1}}\right) \\
&= sign\left\{U_H\, f_g * \left[U_{LL}g_K - U_{LL}g_t + \tfrac{U_L}{g_K}\left(g_{tK}g_K - g_{KK}g_t\right)\right]\right\} \\
&= sign\left[U_{LL}\left(g_K - g_t\right) + \tfrac{U_L}{g_k}\left(g_{tK}\, g_K - g_{KK}\, g_t\right)\right]
\end{aligned}$$

$$\mathrm{Si}\,gn\left(\frac{dK}{d_{\underline{U}_1}}\right)$$
$$= sign\left\{(U_H\ f_g) * \left[U_{LL}g_t - U_{LL}g_K - U_{II}w^2 g_K + \tfrac{U_L}{g_K}\left(g_{tK}g_t - g_{tt}g_K\right)\right]\right\}$$
$$= sign\left[U_{LL}\left(g_t - g_K\right) + \tfrac{U_L}{g_k}\left(g_{tK}\, g_t - g_{tt}\, g_k\right) - U_{II}\, w^2 g_K\right]$$

We know that $U_{LL} < 0$, $g_{KK} < 0$, and $g_{tt} < 0$, but these are insufficient, in general, to sign either $\frac{dt}{d_{\underline{U}_1}}$ or $\frac{dK}{d_{\underline{U}_1}}$. We need to impose additional restrictions on $g_{tK}$, and the relationship between $g_k$, (the marginal productivity of $K$) and $g_t$, (the marginal productivity of $t$), evaluated at their equilibrium levels. We begin by supposing that $t$, the contact time with the patient, and $K$, the physician's expertise, are complements, i.e., $g_{tK} > 0$. Moreover, if $g_K < g_t$, i.e., in equilibrium the marginal productivity of $K$ is lower than that of $t$, then we find that $\frac{dt}{d_{\underline{U}_1}} > 0$. But the impact on $K$ is ambiguous. However if $g_K > g_t$, then we find the opposite, namely that $\frac{dK}{d_{\underline{U}_1}} > 0$. But the impact on $t$ is ambiguous. Suppose, now, that $t$ and $K$ are substitutes, i.e., $g_{tK} < 0$. Then the signs of the comparative statics are ambiguous and require further restrictions on the magnitude of $g_t$ and $g_K$ to reveal their signs. Clearly the policy effect of a change in reservation utility is much more difficult to determine under this scenario than when the patient is the gatekeeper.

For a change in $T$ and $w$ we find that:

$$\mathrm{Si}\,gn\left(\frac{dt}{dT}\right)$$
$$= sign\left[U_{II}w\left(U_H\ f_g\ g_K\right)^2 + \left(U_H\ f_g\ g_K\right)\left(U_H\ f_g\ g_t\right)U_{I_0}\right]$$

$$\mathrm{Sign}\left(\frac{dK}{dT}\right)$$
$$= sign\left[\left(U_H\ f_g\ g_K\right)U_{II}w + \left(U_H\ f_g\ g_t\right)U_{I_0}\right]\left(U_{I_0}w - U_H\ f_g\ g_t\right)$$

$$\mathrm{Si}\,gn\left(\frac{dt}{dw}\right)$$
$$= sign\left[(U_{II}w + U_I)(U_H\, f_g\, g_K)^2 + (U_H\, f_g\, g_K)(U_H\, f_g\, g_t)\, U_{I_0}\right]$$

$$\mathrm{Si}\,gn\left(\frac{dK}{dw}\right)$$
$$= sign\left[(U_H\, f_g\, g_K)(U_{II}w + U_I) + (U_H\, f_g\, g_t)\, U_{I_0}t\right](U_{I_0}w - U_H\, f_g\, g_t)$$

When the physician is the gatekeeper, the effects of both $T$, money transfer to the physician, and $w$, the physician's wage rate, are ambiguous. However if the physician's utility function is linear in income, i.e., $U_{II}$ is equal to zero, then an increase in $w$ or in $T$ will lead the physician to spend more time seeing the patients. However the time to acquire expertise investment still remains uncertain.

Compared to the results with respect to $T$ and $w$ obtained in the empowered patient model , two differences are obvious. First when different parties have the power in the health delivery system, generally $T$ will not have the same effects on the time choices $t$ and $K$. This is also true for the other policy instrument, $w$. Second, whether or not the two income distribution policy instruments will work consistently depends on who has the control. $T$ and $w$ always have the same effect when the patient is empowered. This result will not be sustained when the physician is empowered, especially when the physician's utility function is not linear in income.

## 1.5 The First Stage Analysis

We now turn to the social planner's choice of policy instruments. As the analysis above has underscored, the equilibrium allocation of resources and the distribution of welfare in the second stage depends critically on the structure of the remuneration scheme chosen by the Planner. In stage one, the challenge facing the planner is to choose $T$ and $w$ strategically so as to appropriately influence the behavior of the patient and the physician in stage two.

### 1.5.1 Parameter Determination with an Empowered Patient

Denote the welfare function by $W^1$ when patients are empowered. In the first stage the social planner chooses $T$ and $w$ to maximize $W^1$. Formally, the social planner solves:

$$\begin{aligned}
\underset{T,\,w}{Max}\ W^1 &= \hat{U}_1 + \hat{U}_2 \\
\text{where } \hat{U}_1 &= U_1\left(I_0 - wt^{PA} - T,\ f\left(H_{0,}\, g\left(t^{PA}, K^{PA}\right)\right)\right) \\
&\quad + \lambda^{PA}\left[U_2\left(\begin{array}{c} wt^{PA} + T, 1 - t^{PA} - K^{PA}, \\ f\left(H_{0,}\, g\left(t^{PA}, K^{PA}\right)\right) - H_0 \end{array}\right) - \underline{U_2}\right] \\
\hat{U}_2 &= U_2\left(wt^{PA} + T, 1 - t^{PA} - K^{PA},\ f\left(H_{0,}\, g\left(t^{PA}, K^{PA}\right)\right) - H_0\right)
\end{aligned}$$

Using equations (1.5), (1.6), and (1.7) we can rewrite the first-order conditions as:

$$\begin{aligned}
\frac{\partial W^1}{\partial T} &= -\frac{\partial U_1}{\partial I_0} + \lambda^{PA}\frac{\partial U_2}{\partial I} + \frac{\partial U_2}{\partial I} \\
&\quad + \left(-\frac{\partial U_1}{\partial I_0}w + \frac{\partial U_2}{\partial I}w - \frac{\partial U_2}{\partial L} + \frac{\partial U_2}{\partial \Delta H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t}\right)\frac{\partial t^{PA}}{\partial T} \\
&\quad + \left(\frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial K}\right)\frac{\partial K^{PA}}{\partial T} = 0
\end{aligned} \tag{1.19}$$

$$\begin{aligned}
\frac{\partial W^1}{\partial w} &= \left(-\frac{\partial U_1}{\partial I_0} + \lambda^{PA}\frac{\partial U_2}{\partial I} + \frac{\partial U_2}{\partial I}\right)t^{PA} \\
&\quad + \left(-\frac{\partial U_1}{\partial I_0}w + \frac{\partial U_2}{\partial I}w - \frac{\partial U_2}{\partial L} + \frac{\partial U_2}{\partial \Delta H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t}\right)\frac{\partial t^{PA}}{\partial w} \\
&\quad + \left(\frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial K}\right)\frac{\partial K^{PA}}{\partial w} = 0
\end{aligned} \tag{1.20}$$

Moreover, using expressions (1.15) and (1.17) we notice that

$$\frac{\partial W^1}{\partial T} = \frac{\partial W^1}{\partial w} t^{PA}$$

for all values of $T, w$ (and not merely at a solution to the social planner's optimization problem). This means that, depending upon whether or not $t^{PA}$ is greater or less than 1, the Social Planner will optimally choose to pay the Physician either entirely through capitation, or through wage, but will not generally use both means of payment. This is a striking result in that it suggests that were patients to be empowered to command resources through the health-care system, that it would very possibly be in the context of a system which paid physicians on a capitation basis. This discussion is summed up in the following proposition.

**Proposition 1** When the patient is empowered to command resources, physicians will be paid either exclusively on a capitation basis, or exclusively through a wage scheme. Non-linear remuneration schemes will not be observed.

### 1.5.2 Policy Parameter Choice with an Empowered Physician

Denote by $W^2$ the social welfare function when the physician can choose both $t$ and $K$. The Planner's optimization problem can then be expressed as:

$$\begin{aligned}
\underset{T,\,w}{Max}\ W^2 &= \tilde{U}_1 + \tilde{U}_1 \\
\text{where } \tilde{U}_1 &= U_1\left(I_0 - wt^{PH} - T,\ f\left(H_{0,}\, g\left(t^{PH}, K^{PH}\right)\right)\right) \\
\tilde{U}_2 &= U_2\left(wt^{PH} + T, 1 - t^{PH} - K^{PH},\ f\left(H_{0,}\, g\left(t^{PH}, K^{PH}\right)\right) - H_0\right)
\end{aligned}$$

$$+\beta\left[U_1\left(I_0 - wt^{PH} - T,\ f\left(H_0, g\left(t^{PH}, K^{PH}\right)\right)\right) - \underline{U_1}\right]$$

Using equations (1.8), (1.9), and (1.10) we obtain

$$\begin{aligned}\frac{\partial W^2}{\partial T} &= -\frac{\partial U_1}{\partial I_0} + \frac{\partial U_2}{\partial I} - \beta\frac{\partial U_1}{\partial I_0} \\ &+ \left(-\frac{\partial U_1}{\partial I_0}w + \frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t} - \beta\frac{\partial U_1}{\partial I_0}w\right)\frac{\partial t}{\partial T} \\ &+ \left(\frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial K}\right)\frac{\partial K}{\partial T} = 0 \end{aligned} \tag{1.21}$$

$$\begin{aligned}\frac{\partial W^2}{\partial w} &= \left(-\frac{\partial U_1}{\partial I_0} + \frac{\partial U_2}{\partial I} - \beta\frac{\partial U_1}{\partial I_0}\right)t^{PH} \\ &+ \left(-\frac{\partial U_1}{\partial I_0}w + \frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial t} - \beta\frac{\partial U_1}{\partial I_0}w\right)\frac{\partial t}{\partial w} \\ &+ \left(\frac{\partial U_1}{\partial H}\frac{\partial f}{\partial g}\frac{\partial g}{\partial K}\right)\frac{\partial K}{\partial w} = 0 \end{aligned} \tag{1.22}$$

It is worthwhile stressing that, when the comparative statics results for $\frac{\partial t}{\partial T}$, $\frac{\partial K}{\partial T}$, $\frac{\partial t}{\partial w}$ and $\frac{\partial K}{\partial w}$ are substituted into the above expressions, we do not obtain a proportional relationship between $\frac{\partial W^2}{\partial T}$ and $\frac{\partial W^2}{\partial w}$ as we did when the patient was empowered. Although it is true that $\frac{\partial W^2}{\partial T} < \frac{\partial W^2}{\partial w}$ whenever $t > 1$; thus it is possible that $\frac{\partial W^2}{\partial T} < 0$ when $\frac{\partial W^2}{\partial w} > 0$. It is clear that neither $T$ nor $w$ will generally be zero. In particular, it is quite possible that at the social welfare optimum it may be desirable to have a negative lump-sum transfer (e.g., the present value of subsidized medical education), and a positive wage remuneration scheme.

**Proposition 2** When the physician is empowered to manage the resources of the health-care system, it is generally optimal to use a non-linear compensation scheme, combining both fixed and variable components.

## 1.6 Discussion and Conclusions

In recent years, with unsurpassed access to internet resources, patients are becoming more sophisticated in their interactions with medical practitioners, particularly when it comes to treatment options. They expect - and indeed demand - greater involvement in determining the course of care for medical conditions. As computer-based diagnostic tools become more developed, it is natural to imagine that patients will expect to access specialists and other health care professionals directly. This would entail a significant transformation of our present system, in which the physician controls access to health-care resources. Indeed, some might argue that allowing sophisticated patients to deal directly with specialists might ultimately promote a more efficient use of health care resources, by cutting out unnecessary intermediaries.

This chapter uses a simple model to investigate the role of the gatekeeper in influencing resource allocation in the health care sector. In order to highlight the importance of the gatekeeper role, it is assumed that there is no informational asymmetry between the patient and the physician. The production of health care services depends upon the amount of contact time, $t$, between the patient and the physician, and also on the investment of the physician in expertise, $K$, which is assumed to be non-contractible. When the patient is empowered the patient chooses $t$. In contrast, when the physician acts as the gatekeeper the doctor chooses $t$. In both cases, because $K$ is non-contractible, it is the physician who chooses $K$. We assume that the publicly-funded health-care system pays physicians only for their contact time, and not for their investments in expertise. The production of health-care services, however, depends on both $t$ and $K$: in particular, the higher the level of $K$, the more productive is actual time allocated to doctor-patient visits.

Comparing the choice of clinical time, $t$, and expertise, $K$, when the physician is the gatekeeper versus when the patient takes this role, is revealing. For instance, for any given level of quality (expertise investment), the patient chooses more clinical time than is chosen by either the social planner or the physician. For any given level of quantity (contact time), the physician chooses to invest less in expertise than is required for efficiency, but more than is chosen when the patient is the gatekeeper. So, even in the absence of informational asymmetries, institutional arrangements with respect to accessing health care services matter when it comes to determining clinical time and investments in expertise. The model can be used to provide some insight into the current tension between the demand for services on the part of the patient and the supply of these services. While the focus in the popular media and elsewhere lies on the shortage of physicians, our analysis suggests that the problem is potentially compounded by the fact that physicians do not have the incentive to supply as many clinical hours as would be chosen by the patients were they in control. One reason for this tension between patient and physician is the fact that quality, $K$, is non-contractible. Physicians control $K$ and would like to invest more time in expertise, for any given level of clinical contact, than would be determined when the patient is the gatekeeper. Thus, the complaint by physicians that they have insufficient time to conduct research stems, in part, from the incentive effects emanating from who controls access to resources.

Another central concern of this paper is the design of the remuneration scheme for the physician. The government is given the choice of using a non-linear remuneration scheme, so that physician income is determined as the sum of a fixed payment and a variable (contact time) component. Intriguingly, when the patient is empowered, it is shown that it might be optimal to pay the physician a flat fee which is independent of $t$. In contrast, when the physician is empowered, it is typically desirable to use a non-linear compensation scheme, combining both fixed and variable elements. Again, these results are significant in terms of the broader debate over possible reforms to our existing health care system, and the desirability (or not) of introducing some element of capitation into physician payment schemes.

Who controls access to health resources clearly matters. It matters in terms of the amount of clinical time spent with the patient and it matters in terms of the quality of this time. Some of the recent concerns arising in the health-care system may be stemming, in part, from the challenge by patients to have more control over the services they receive. The results of this paper also suggest that the ability of policy makers to influence health-care decisions depends critically on the institutional arrangement governing access to health care, rendering the question of who is gatekeeper a potentially important one to address in the context of health-care reform.

This model can fruitfully be extended in a number of different directions. It is clear that it would be interesting to examine the importance of patient myopia in this analysis: here, we have assumed that patients do not see through the public sector budget constraint, and this is perhaps not entirely realistic: consumers do understand, at least to some degree, that the health-care system is financed by their taxes. It would also be very interesting to see how the results change – if at all – when one introduces a heterogeneous patient population (with respect to income and/or health status), or if one were to introduce some notion of patient cost in becoming informed about the most appropriate diagnosis and treatment for a particular medical condition.

# Chapter 2
# Wealth, Health, and the Pursuit of Happiness

## 2.1 Introduction

Public health commentators have long bemoaned the fact that, despite general economic prosperity, many citizens in Western countries live an (increasingly) unhealthy lifestyle, leading to poor health outcomes. According to the World Health Organization, cancer rates are projected to increase by 50% in the next twenty years, unless people in countries such as Britain and the United States significantly modify their lifestyle choices (WHO 2001). The relationship between increased household wealth and lifestyle choices is also illustrated by the growing prevalence of obesity. Obesity rates have risen sharply in all countries, and some specialists have claimed that the global epidemic of obesity is "out of control".[11] This stylized fact has lead researchers to investigate the reasons for which individuals fail to make healthy choices regarding to nutrition and exercise. One hypothesis is that a healthy lifestyle may not be affordable: individuals may not have enough income to buy high quality food or the opportunity to undertake regular exercise. However, affordability is clearly not the entire story; many individuals, who clearly have an income adequate to support healthy lifestyle choices, make unhealthy choices with respect to nutrition, exercise, and

[11] BBC news, October 31, 2004.
URL:http://news.bbc.co.uk/1/hi/world/africa/3969693.stm

other factors correlated with good health. This therefore begs the question: Why is the pursuit of happiness not also the pursuit of wellness?

An impressive body of empirical research has explored the link between health and wealth. It has found, by and large, that individuals with higher incomes are healthier than those who are poorer (Ettner 1996, Deaton and Paxson 1998, Smith 1999, Marmot and Wilkinson 1999, Case *et al.* 2002). Several explanations have been given as to why income may influence health, of which three are particularly interesting. One hypothesis is that the positive relationship between income and health reflects the fact that wealthier individuals have better access to medical services and health care (Decker and Remler 2004). If this were the case, one would expect this relationship to disappear in jurisdictions countries with well-developed public health systems. However, evidence from Canada, where most health services are publicly insured, indicates that the observed income-health relationship persists despite virtually universal access to health-care services (Humphries and van Doorslaer 2000, Buckley *et al.* 2004).[12]

An alternative hypothesis is that income is an indicator of the level of education. More educated people are typically more knowledgeable about the link between health outcomes and lifestyle choices, and thus they will make healthier lifestyle choices than their less educated counterparts (Lleras-Muney 2002). Yet empirical analyses find that a positive relationship between wealth and health outcomes persists even after controlling for differences in education, which casts doubt on the importance of this potential channel (Chou *et al.* 2005, Ettner 1996, Nayga 2000). Finally, it has been hypothesized that

[12] The next section elaborates on the literature looking at the relationship between income and health status.

income matters because people with greater financial resources are simply able to afford superior exercise programs as well as higher quality food, enabling them to better balance their intake of calories with exercise (Marmot 2002). However, empirical investigations to date have not been able to conclusively establish that the real problem is the affordability of recreational opportunities or high-quality diets. Instead, people living in poor neighbourhoods seem to encounter the issue of availability. Empirical evidences have shown that residents of poor neighborhoods have more limited access to high-quality food and fewer safe places for leisure-time activities compared with residents of wealthier neighborhoods (Morland *et al.* 2002, Brownson *et al.* 2001, Romero 2005).

Whereas contributors to the public policy debate from the medical community generally assume that consumers who can afford to choose a healthy lifestyle would want to do so – and therefore, there must be some barrier preventing citizens from making health-maximizing choices – the economic model of rational individual choice situates individual decisions about exercise and nutrition within the broader context of utility maximization. This paper presents a theoretical model of individual choice which illuminates the relationship between health, wealth, and the pursuit of happiness. Importantly, healthy lifestyle choices are modelled not as an end in themselves, but as a means to obtain greater overall life-satisfaction.

This paper clearly demonstrates that individuals who are maximizing utility will generally not make lifestyle choices which maximize their health. In fact, it is rational for individuals to make "unhealthy" choices when it comes to nutrition and exercise: individuals will over-eat and under-exercise relative to health maximizing choices. Yet this model also shows that as individuals get wealthier, the gap between utility-maximization and health-maximization will narrow. In other words, the reason that we observe a positive relationship between health and income is simply because health is a normal good: as individual income rises, it is utility-maximizing to choose a healthier lifestyle.

In addition, this paper compares different strategies for health promotion. Using average health status as an indicator of population health, it investigates the effectiveness of income redistribution versus a targeted health promotion policy. It shows that an income redistribution policy may lead to a net increase in population health and in social welfare. In contrast, policies which specifically target lifestyle choices may succeed in persuading citizens to choose a health-maximizing lifestyle, but result in a net welfare loss to society.

This paper is structured as follows. Section 2 reviews the related literature. Section 3 presents a simple model to illustrate the distinction between health maximization and utility maximization by rational individuals. Comparison between these two choice frameworks highlight the "fat and happy" rationale. Comparative statics results and simulations are also presented in this section. A number of policy experiments are considered in Section 4, and Section 5 concludes. The proofs as well as a graph and simulation table are contained in the Appendix.

## 2.2 Related Literature Review

The positive relationship between health and wealth is well documented by a vast empirical literature. It has been shown that higher income is associated with better health in both developed and developing countries. van Doorslaer *et al.* (1997) compare income-related inequality in health across nine industrialized countries, and show that significant income-related health inequality exists, favoring high income earners in all the nine countries. Banerjee *et al.*(2004) study the relationship between wealth and health in a poor rural area of the state of Rajasthan in India. Their research finds the evidence that individuals with lower economic status also have worse health status. Similar empirical results have been obtained in the Canadian context, despite a publicly funded health care system with universal coverage. Cairney and Arnold (1996) examine the socio-economic determinants of self-assessed health in elderly non-institutionalized Canadians. Among all the class indicators they find that income is the most consistent class predictor of different health measures. High income people have much better self-assessed health. Mustard *et al.* (1997) describe age-specific socioeconomic differentials in morbidity and mortality, paying special attention to people between 30 and 64. It is shown that the negative effects of socioeconomic status on morbidity and mortality are more consistently found for income than for other socioeconomic factors for this age group. Humphries and van Doorslaer (2000) study the degree of income related inequality in health in Canada. Their paper not only presents compelling evidence of income related inequality in health, but also finds that the degree of such inequality in Canada is significant higher than reported in previous work.

Correlation is not causation. Individuals might be healthier because they are wealthier. However it is also possible that individuals in good health could perform better in the labor market and thus be able to earn higher incomes. A second group of the empirical papers have explicitly studied the existence of a causal relationship between income and health outcomes. These papers have convincingly argued that a "thick wallet" improves individual health. Ettner (1996) estimates the structural impact of income on a series of health outcome measures, and shows that an increase in income significantly improves both mental and physical health. To avoid the difficulties faced in untangling the direction of causality in the relationship between household income and health in adulthood, Case *et al.*(2002) examine the relationship between household income and the health status of children.[13] Children from families with higher household income have much better health status, and this relationship becomes more pronounced for older children. Using longitudinal data for individuals aged 50 and older, Buckley *et al.*(2004) examine the effect of income and education on health transitions. They choose a sample in which all the individuals were initially in good health and study the changes in health status over the subsequent years. They found that the probability of remaining in good health declines from higher income to lower income levels.

In contrast to the extensive empirical literature examining the relationship between wealth and health, there have been few theoretical analyses of this issue. Grossman (1972) constructed a theoretical model to investigate the demand for health. In his model health is viewed as a capital good, which depreciates with age and can be improved through investment. This framework indicates that the demand for health is positively related to the wage rate. Contoyannis and Forster (1999) also develop a theoretical model, in which individuals are differentiated according to their underlying health characteristics. They examine the relationship between an individual's expected health and changes in income. They con-

[13] It should be noted that a reverse causality may also exit. Sick children need parental care. Some parents may have to take time off from work and lose pay.

cluded that equiproportionate income growth may increase both average population health and inequalities in health within a population.

The modelling strategy in this paper is quite different from those in the previous two papers. Unlike Grossman, which is essentially a human capital model with a depreciable investment good, the model of health production used here is a simplified view of the physiological relationship between food intake and exercise and the production of health. In particular, in this paper all consumers who have income greater than a certain threshold level are able to choose a lifestyle that would allow them to attain perfect health. Perfect health is thus affordable for most people and can be attained with appropriate choices. In contrast, Grossman (1972) defines perfect health as 365 healthy days, which is actually an upper bound for health and thus not a feasible choice for most people. Contoyannis and Forster (1999) develop an analytic framework that enables them to study variation in the distribution of population health as income changes, but their model does not capture the relationship between individual preferences and lifestyle choices. The simple model in this paper enables us to examine both individuals' behaviors and changes in population health.

Some economic studies have examined the issue of individual lifestyle choices, seeking to explain the prevalence of unhealthy behaviors. Levy (2002) develops a dynamic model to examine individuals' lifetime non-addictive eating behaviors. A rational person gains utility from the consumption of food. However too much or too little food consumption leads to deviation from appropriate weight, and thus increases the risk of death. It is shown that, in the absence of socio-cultural norms, lifetime utility maximizing individuals are overweight in the steady state. Socio-cultural norms reduce the deviation of individual choices from those which maximize health. Bednarek *et al.*(2003) develop a model examining how a rational agent makes health choices by trading off the cost of being healthier against the benefits of greater consumption and leisure. They find that individuals whose return on health is low will deliberately choose to be less healthy (lower health status) but happier (higher level of utility).

In contrast to these papers, the model studied here treats the production of health in a more sophisticated fashion, allowing individuals to balance higher food intake with greater exercise. And, unlike either theoretical paper, the framework enables us to study not only the relationship between health and income, but also the impact of alternative public policy initiatives on the distribution of both population health and social welfare.

## 2.3 Model

We consider a representative agent model in which individual utility depends both on health status $H$ and a "satisfaction function" $V$.[14] A higher level health status $H$ corresponds to better health, and therefore a greater capacity to live life fully. The determinants of health are food consumption, $F$, and exercise $X$. For the purposes of this analysis, the good things in life are assumed to be food and a composite of other consumption goods, $S$, which do not affect health directly. $S$ may be viewed as an aggregate of all commodities that contributes to life satisfaction but not to individual's health status.[15] These variables

[14] Wealth is normally defined as accumulated money and precious possessions. The theoretical model in this chapter is a static one and thus no time dimension is involved, hence an individual's income represents his wealth.

[15] For convenience, we refer to $S$ as sedentary leisure activity. Note although sedentary leisure activity does not affect health directly it has an indirect negative effect on health, either through the decreased observed income (see page 52) or through decreased exercise due to a substitution effect.

are the only arguments of $V$, the satisfaction function. We assume that $X$, exercise, does not contribute directly to life satisfaction $V$, but contributes to overall utility through its influence on health status $H$. The utility function postulates that overall personal happiness is a product of health status, $H$, and life satisfaction, $V$:

$$U = H(F, X)\, V(F, S)$$

We assume that the relationship between food, exercise, and the production of health is described by a quadratic functional form as follows:

$$H = g(F, X) = b(F - \delta X) - c(F - \delta X)^2$$

where $b, c$, and $\delta$ are exogenously determined constants. This health function is intended to provide a stylized representation of the biomechanical relationship between food, exercise, and health status.[16] There are several key features of this representation which are important to underscore. Firstly health status is zero if the person neither eats nor exercises, i.e., $H(0, 0) = 0$, which means that $U = 0$ too. If you don't eat, you die, and therefore take no pleasure in life. Secondly, there is a maximum level of health – it is impossible to become "infinitely healthy" through consumption of appropriate amounts of food and exercise. Thirdly, the relationship indicates that food and exercise may improve health, but too much of either can decrease health status. With a fixed level of exercise, health status increases as food consumption increases until it reaches the upper bound of perfect health, and then deteriorates if food consumption increases further. The same rule

[16] The selection of this particular functional form is made for illustrative purposes – that is, we believe that the behaviour of this functional form is broadly consistent with actual physiological relationships. It is not meant to represent exactly the way in which food and exercise interact to produce health.

applies to exercise. Given a certain level of food, heath status increases with consumption of more exercise. However too much exercise can lead to a deterioration in health – for example, if you consume no food, but undertake exercise, your health status will in fact be negative. Importantly – and as is consistent with the stylized facts – there is no unique combination of levels of consumption of food and exercise that maximize health: there are infinitely many ways of achieving perfect health, and they require a balance of caloric intake and physical activity. The more food a person consumes, the more exercise is required to remain fit and healthy. We assume that there is a constant trade-off between food and exercise: 1 unit of exercise burns up $\delta$ units of food consumption.[17]

Given the specific quadratic form of the health status function we have that:

$$H_F = -\frac{1}{\delta} H_X \tag{2.23}$$

$$H_{FF} = \frac{1}{\delta^2} H_{XX} = -\frac{1}{\delta} H_{FX} \tag{2.24}$$

where $H_F$ and $H_{FF}$ denote the first and second derivatives with respect to food, and $H_X$ and $H_{XX}$ denote the first and second derivatives with respect to exercise.

Life satisfaction $V$ is assumed to be a strictly concave function in food $F$ and sedentary leisure activity $S$. Both bring the pleasure to individuals' life, though the increased pleasure from consumption of food and sedentary activity is decreasing. Thus for the life satisfaction function $V$ we have:

$$V_S > 0, V_F > 0, V_{SS} < 0, V_{FF} < 0$$

[17] Again $\delta$ is chosen for illustative pupose of energy accouting only. For a more detailed description and empirical modeling on calorie consumption and expenditure, see Cutler *et al.*(2003).

where $V_F$ and $V_S$ denote the first derivatives of the satisfaction function with respect to food and sedentary activities, and $V_{FF}$ and $V_{SS}$ the second derivatives. The agent is assumed to have exogenous full money income, $M$, which must be allocated between the consumption of $F$, $X$, and $S$. All three consumption goods are assumed to be produced by competitive markets, and can be acquired at constant per unit cost.

### 2.3.1 Maximizing health

As a first exercise, we consider what choices are required in order to maximize individual health.[18] To achieve perfect health, the representative agent has to solve the following problem:

$$\underset{F,X}{Max} \;\; H = b(F - \delta X) - c(F - \delta X)^2$$

The first order conditions require that:

$$H_F^h = b - 2c(F - \delta X) = 0 \tag{2.25}$$

$$H_x^h = -\delta[b - 2c(F - \delta X)] = 0 \tag{2.26}$$

In order to achieve perfect health, one must appropriately balance food and exercise. There is a continuum of solutions to this system of first order conditions: there exist many different eating and exercise combinations which keep people healthy. A person who loves food can consume as many calories as they want, as long as they undertake enough exercise to keep themselves fit. Less exercise is needed for a person with a small appetite. As long as food

[18] For this purpose budget constraint is not included in the maximization problem.

and exercise are balanced, perfect health (equal to $\frac{b^2}{4c}$) will be achieved.[19] The perfect health requires a balance between $F$ and $X$ as follows:

$$F^h - \delta X^h = \frac{b}{2c} \tag{2.27}$$

A perfectly healthy individual may consume any level of $S$ depending on his/her budget constraint. Clearly achieving optimal health depends only on the relationship between food and exercise.

Equation (2.27) represents a necessary condition for individuals to achieve perfect health, but not a sufficient one. It is feasible for individuals to achieve perfect health only if a health-maximization consumption bundle is affordable. Denote the price of food, the price of exercise, and the price of sedentary activity as $p_f$, $p_x$, and $p_s$ respectively. Substituting equation (2.27) into the budget constraint we have:

$$p_f\left(\delta X^h + \frac{b}{2c}\right) + p_x X^h + p_s S^h = M$$

At the extreme case where both $X$ and $S$ are equal to zero, the above equation cannot hold unless income is no less than $\frac{b}{2c}p_f$. Thus health status cannot be maximized unless income is greater than or equal to $\frac{b}{2c}p_f$. For people with income lower than this level, perfect health is not in the feasible set. It is an empirical question as to whether or not affordability is really a significant factor in explaining the distribution of health status in contemporary society. On the one hand, this result is consistent with the literature on poverty and health, which has shown that people living in poverty are at a higher risk

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[19] The first-order condition for health maximization requires $F - \delta X = \frac{b}{2c}$. Substituting this result into health function we have: $H^{perfect} = b(\frac{b}{2c}) - c(\frac{b}{2c})^2 = \frac{b^2}{2c} - \frac{b^2}{4c} = \frac{b^2}{4c}$.

of being unhealthy (Benzeval et al. 2000, Phipps 2003, Drewnowski and Specter 2004). On the other hand, the relative price of food has sharply decreased over the past several decades, which suggests that this threshold level may not be a significant obstacle for most consumers were they to choose to pursue perfect health.

### 2.3.2 Maximizing happiness

Economists believe that individual choices are driven by utility maximization. Consumers do not set out to maximize health, but to maximize happiness. In this section, we investigate the choices made by a utility maximizing individual, faced with a budget constraint, and examine whether or not these choices also maximize health.

The representative agent must then solve the utility maximization problem:

$$\begin{aligned} \underset{F,X,S}{Max}\ U &= H * V = [b(F-\delta X) - c(F-\delta X)^2] * V(F,S) \\ subject\ to &: p_f F + p_x X + p_s S = M \end{aligned}$$

The budget constraint presented here can be interpreted as implicitly incorporating a labor-leisure choice by the consumer. The constraint can be written as: $p_f F + p_x X + p_s S = wL$, where $L$ denotes the total available time and $wL$ denotes the full earning capacity. Setting $p_s = w$, i.e., the opportunity cost of sedentary activities is foregone labour market income, we obtain that $p_f F + p_x X = w(L - S)$, which clearly reflects the labor-leisure choice. The budget constraint used above is therefore a more general formulation, because it allows for the possibility that the cost of engaging in sedentary activity or exercise may be greater, for example, than merely foregone income. In addition, although "full income" $M$ (or, equivalently, the wage rate, $w$) is defined as exogenous in this model, actual observed income, $wL - p_s S$, is endogenous.

The first order conditions are:

$$F : H_F V + H V_F - \lambda p_f = 0 \quad (2.28)$$

$$X : H_X V - \lambda p_x = 0 \quad (2.29)$$

$$S : H V_S - \lambda p_s = 0 \quad (2.30)$$

$$\lambda : p_f F + p_x X + p_s S = M \quad (2.31)$$

We denote a solution to the above system of first-order conditions as $(F^*, X^*, S^*, \lambda^*)$. Equations (2.28) to (2.30) require that the marginal rate of substitution between any two of the goods be equal to the respective price ratio, the economic rate of substitution. Equation (2.31) is just the budget constraint. By manipulating equations (2.23), and (2.28) to (2.30) we have:[20]

$$V_F = \left(p_f + \frac{p_x}{\delta}\right) \frac{1}{p_s} V_S \quad (2.32)$$

Equation (2.28) implies that at a solution to the utility maximization problem a marginal increase in exercise improves health, that is, $H_X^*$ is greater than zero. Equation (2.23) shows that the sign of $H_F$ is always opposite to the sign of $H_X$. Consequently, $H_F^*$ must be less than zero at any solution to the utility maximization problem. In effect, this result means

[20] Equation (2.23) indicates that $H_X = -\delta H_F$. Substituting this result into equation (2.29) we have $V = -\frac{\lambda p_f}{\delta H_F}$. Thus we can rewrite equation (2.28) with some rearranging as:

$$H V_F = \lambda p_f - \frac{\lambda p_f}{\delta H_F}$$

Comparing this expression to equation (2.30) leads to the result shown in equation (2.32).

that a person who seeks to maximize happiness will overeat and underexercise relative to what would be required in order to maximize health status. Although less food and more exercise would enable the individual to achieve greater health, this is inconsistent with achieving the greatest personal happiness in life. Being "fat and happy" is rational. The majority of the population, whose income is sufficient to afford a health-maximizing consumption bundle, prefers some sacrifice of their health status to obtain a higher overall life happiness.

### 2.3.3 The relationship between income and health status

Existing literature has identified a clear positive relationship between health status and income. There has been considerable speculation as to why this relationship exists, i.e., are individuals with greater income able to purchase better quality food? Do they have a better understanding of the relationship between food consumption, exercise, and health status? Or is there some other factor working? This section investigates the impact of variation in the level of income, and in the prices of the different consumption goods, on individual choices with respect to the consumption of food, exercise and leisure activity, giving some insight into the different channels by which income influences health status.

To investigate these relationships, we undertake a comparative statics exercise. Totally differentiating equations (2.28) to (2.31) we obtain:

$$\begin{aligned} -p_f\,dF - p_x\,dX - p_s\,dS &= -\,dM \\ -p_f\,d\lambda + a_{11}\,dF + a_{12}\,dX + a_{13}\,ds &= \lambda\,dp_f + (H_{FF}VX + H_F V_F\,X)d\delta \end{aligned}$$

$$
\begin{aligned}
-p_x\, d\lambda + a_{21}\, dF + a_{22}\, dX + a_{23}\, dS &= \lambda\, dp_x + (H_F V - H_{FF} V X \delta) d\delta \\
-p_s\, d\lambda + a_{31}\, dF + a_{32}\, dX + a_{33}\, dS &= \lambda\, dp_s + (H_F V_S X) d\delta
\end{aligned}
$$

where

$$a_{11} = H_{FF}V + 2H_F V_F + H V_{FF} < 0 \tag{2.33}$$

$$a_{12} = H_{FX}V + H_X V_F = -\delta(H_{FF}V + H_F V_F) > 0 \tag{2.34}$$

$$a_{13} = H_F V_S + H V_{FS} \tag{2.35}$$

$$a_{22} = H_{XX}V = \delta^2 H_{FF} V < 0 \tag{2.36}$$

$$a_{23} = H_X V_S = -\delta H_F V_S > 0 \tag{2.37}$$

$$a_{33} = H V_{SS} < 0 \tag{2.38}$$

Using Cramer's rule, we calculate that:

$$
\begin{aligned}
\frac{dF}{dM} &= \frac{a_{23}^2 p_f - a_{22}a_{33}p_f - a_{13}a_{23}p_x + a_{12}a_{33}p_x + a_{13}a_{22}p_s - a_{12}a_{23}p_s}{\mid \bar{H} \mid} \\
\frac{dX}{dM} &= \frac{-a_{23}a_{13}p_f + a_{12}a_{33}p_f + a_{13}^2 p_x - a_{11}a_{33}p_x - a_{13}a_{12}p_s + a_{11}a_{23}p_s}{\mid \bar{H} \mid} \\
\frac{dS}{dM} &= \frac{a_{22}a_{13}p_f - a_{12}a_{23}p_f - a_{12}a_{13}p_x + a_{11}a_{23}p_x + a_{12}^2 p_s - a_{11}a_{22}p_s}{\mid \bar{H} \mid}
\end{aligned}
$$

where $\mid \bar{H} \mid$ represents the determinant of the bordered Hessian matrix. We further assume that $V_{FS} \geq 0$, that is, food and sedentary activity are compliments with respect to the generation of life satisfaction.[21] Substituting the results from equation (2.33) to (2.38) and equation (2.32) into the expressions for $dF/dM$, $dX/dM$ and $dS/dM$ we find that each of these expressions are positive: increased income will lead to an increase in the

[21] $V_{FS} > 0$ implies that the pleasure couch potatoes derive from watching TV is increased when TV viewing is accompanied by the consumption of a bowl of chips.

consumption of food, of exercise, and of sedentary activity. This analysis is summarized in the Proposition below.

**Proposition 3** Food, exercise, and sedentary activity are all normal goods for a utility maximizing individual.

**Proof.** *See Appendix.* ■

With respect to the debate in public health circles on the relationship between income and health, the above proposition suggests rich people eat better and exercise more simply because they are wealthier. Poorer individuals would make same choices if they had the same income. The most intriguing result is that exercise increases with higher income. Note exercise does not in itself contribute to life satisfaction: it contributes only indirectly to overall utility, through its influence on health status. With extra income, an agent spends more on both $F$ and $S$, taking advantage of the complementary characteristics between food and sedentary activities. Given that health status scales the utility function, when consumption of $F$ increases, the agent needs to increase $X$, to maintain a sufficiently high health status.

The fact that the consumption of both food and exercise increases with income does not imply that actual health status will also increase with income. In effect, if a given rise in income leads to a significant increase in food consumption, and only a modest uptick in exercise, then higher income may lead to worsened health. Using the comparative statics results, however, we investigate explicitly the relationship between income and health. Totally differentiating the health status function with respect to $M$, we obtain that:

$$\frac{dH}{dM} = \frac{dg}{dF}\frac{dF}{dM} + \frac{dg}{dX}\frac{dX}{dM} = H_F\frac{dF}{dM} + H_X\frac{dX}{dM} = H_F\left(\frac{dF}{dM} - \delta\frac{dX}{dM}\right)$$

The following proposition is the immediate result:

**Proposition 4** Income and health status are positively correlated. Richer people have better health.

**Proof.** *See Appendix.* ■

The prediction of our theoretical model is therefore consistent with the large body of empirical research which has investigated the positive relationship between social-economics status and health outcomes. We show that as individuals become richer, they consume more of all of the things in life that generate satisfaction, that is, both food and sedentary activity. In addition, they have the financial means to balance their increased caloric intake with additional exercise, and in fact will get closer and closer to a combination of food and exercise that would maximize their health status. In effect, as one gets richer, devoting the resources necessary to achieve a higher level of $H$ becomes a cost-effective means of achieving higher overall happiness. Greater wealth brings greater health *and* greater happiness.

It is also useful to investigate the impact of changing relative prices on the pattern of individual consumption. Applying Cramer's rule, as above, we show that $dF/dp_f < 0, dS/dp_s < 0$, and $dX/dp_x < 0$. Cross-price effects are shown to be ambiguous, and we summarize the results in the following proposition:

**Proposition 5** People tend to eat more when food is cheaper and to sit longer in front of the screen when sedentary activity is less expensive. They also choose to exercise more when it is more affordable even though exercise does not contribute to happiness directly.

Proof. See Appendix. ■

**Proposition 6** The demand for food may increase or decrease if the price of either exercise or sedentary activity increases. Cross-price effects are also ambiguous for exercise and sedentary activity.

Proof. See Appendix. ■

These comparative statics results are interesting from the point of view of the public policy debate on appropriate health policies. Proposition 5 – which is essentially nothing other than the *Law of Demand* – supports the proponents of 'fat taxes', who argue that making food relatively more expensive will lead to reduced expenditure on groceries. However, the ambiguous cross-price effect shown in Proposition 6 suggests that the overall impact of a tax on food might not be entirely successful as a strategy for promoting increased health: if $dX/dp_f < 0$, then exercise will be reduced as well as food consumption, and the overall impact on health status is generally ambiguous.

Another interesting public policy issue is the relationship between health (and happiness) and the nature of the physical exercise undertaken by individuals. $\delta$ in our model can be interpreted as a measure of exercise intensity. When individuals run or swim, rather than just walk, they will burn off more calories for each hour spent exercising. Public policies like the construction of community recreation centres with indoor swimming pools or running tracks, may encourage individuals to choose more intensive forms of physical exercise. Using the same techniques as above, we can establish the following proposition with respect to $\delta$:[22]

**Proposition 7** An increase in $\delta$ (more intensive exercise) leads to increased consumption of food but does not improve individual health as long as the elasticity of marginal benefit on health from exercise is greater than 1. A higher degree of intensity has an ambiguous effect on the absolute level of consumption of exercise and of sedentary activity.

**Proof.** See Appendix. ■

This result suggests that the intensity of exercise does not have a clear role on individuals' health improvement. Holding price constant, if individuals choose a more intensive form of exercise they may tend to eat more, and their overall health may in fact worsen. This is because choosing a more intensive exercise may lead individuals to exercise not much more, or even less, and thus health status deteriorates. In this sense, jogging might not be more helpful in health improving than strolling. This result also suggests that making availability of a greater density of recreational facilities, such as indoor swimming pools and running tracks, will not necessarily lead to improvements in population health.

[22] Since food $F$ and exercise $X$ are interacting with each other and the relationship between them is nonlinear, it is difficult to identify the magnitude of the elasticity of marginal benefit on health from exercise in this model. When the elasticity is less than 1, an increase in the intensity of exercise has an ambiguous effect on the consumption of food and individual health.

### 2.3.4 The Simulation Model

It is interesting to undertake a simple simulation of the theoretical model. Whereas the analysis developed above establishes that a positive relationship must exist between wealth and health, uncertainty regarding the sign of third derivatives precludes the articulation of any conclusions with respect to the shape of such relationship. From the point of view of public policy making, the shape of this relationship is important: for example, if this relationship is concave, then significant gains in population health may result from a relatively modest increase in income redistribution.

Maple V is used to undertake this simulation exercise. The simulation results are developed under the hypothesis that health production function and utility function have the following specification:

$$\begin{aligned} H &= g(F,X) = 2(F-\delta X)-(F-\delta X)^2 \\ U &= \left[2(F-\delta X)-(F-\delta X)^2\right]\left(10F^{\frac{1}{4}}S^{\frac{1}{2}}\right) \end{aligned}$$

This specification has the following important features. Firstly, health status, which scales the life satisfaction function $V$, is defined over the interval $[0,1]$. Perfect health is defined as 1 while extremely poor health status will be represented by a number very close to 0. Secondly, the life satisfaction function $V$ is concave both in food $F$ and sedentary activities $S$, and $F$ and $S$ are complementary to each other in the function $V$.

The computational strategy is as follows: we solve for the equilibrium given all the exogenous variables, and then substitute these results into the health production function to find the health status at the solution to utility maximization problem. It is then straightforward to determine the relationship between health and wealth in equilibrium.

With $\delta = 0.1$; $p_f = 0.5$; $p_x = 0.8$; $p_s = 0.4$; and with $L$ from 20 to 200 we have the following results.[23] Firstly, as income increases an individual increases his consumptions of all three goods. Interestingly, we observe a big jump in exercise consumption when the individual's income increases from 20 to 30 (see graph 1); the rate of increase diminishes sharply thereafter. Secondly the simulation results show that individuals always overeat and under-exercise as compared to what would be required for perfect health. In this simulation example, perfect health requires that $(F - \delta X)$ be equal to 1, whereas this number is always greater than 1 when utility is maximized. However the number gets closer and closer to 1 as income increases. Thirdly, and most importantly, we observe an increase in health status over the range of income, as is illustrated in the graph 1 in the appendix[24]:

What this graph tells us, which is not indicated by comparative statics analysis, is the shape of relationship between health status and income. By this simulation example not only do we find that individual's health status will increase as income increases, we also observe that this rate of increase will be decreasing at higher income level. The concavity of the health status curve indicates that the health outcome for the same amount of money transfer will be different depending on who receive the transfer. In other words, a transfer of \$1 from a wealthy individual to a poor one will improve the health of the poor individual

[23] Different sets of parameters have been used to conduct the simulation. This set of parameters is selected in order to illustrate the shape of health and income most clearly.

[24] The simulation results do not show a big difference in health status between the rich and the poor. This is due to the specific multiplicative form of the utility function $U = HV$. An individual faces a strong incentive to maintain good health, since reduced health leads to a large loss in overall happiness.

by more than the health of the wealthy individual falls. Thus if the population health is defined as the average health status of a community, an income redistribution policy will increase population health.

## 2.4 Policy Experiments

The preceding analysis has underscored the fact that the maximization of health and the pursuit of happiness leads to different choices at the level of the individual. It is natural to extend this investigation to the level of the population, and to examine the extent to which the maximization of social welfare may – or may not – be consistent with the maximization of population health. In this section we consider a number of policy experiments which enable us to investigate the impact of different fiscal policies both on the distribution of welfare, and on some measure of population health. Public health commentators have argued that public policies which affect the distribution of income will also affect the health of the population.[25] The results reported below give precise meaning to this claim.

Before investigating the impact of income redistribution on population health, note that it is straightforward to establish that income redistribution can be justified on the grounds of improved social welfare. The result follows immediately from the fact that individual utility functions are concave in income, and individual preferences are identical.

[25] For example, see Allison and Wilkinson (1991), accessible via the website of Socialist Health Association. URL: http://www.sochealth.co.uk/Incomehealth/ch1.html

### 2.4.1 Income redistribution and health improvement

We assume that the population is differentiated according to income. Since the analysis above has shown that health status is increasing with income, rich people are healthier than those who are poor – a phenomenon which is broadly consistent with the socioeconomic gradient for health. This fact suggests that implementing an income redistribution policy will have a significant impact on the distribution of health in the community: the health status of the recipients of income transfers will improve, whereas the health status of high-income taxpayers will decrease. Will implementing such a policy increase or decrease population health?

A challenge in addressing this issue is to define what is meant by "population health". Conceptually, many of the same issues arise as when seeking to measure social welfare, or poverty. Depending upon the weight attached to health of particular individuals, opinions may differ as to whether or not a given policy measure has in fact improved population health. Below, we assume that the health of the population can be measured as the average health status of the members of the community, which is analogous to using a Benthamite social welfare function.

Given the assumption that the utility function is concave in all three consumption goods, food, exercise and sedentary activity, it is straightforward to establish that implementing an income redistribution policy using lump-sum taxes and transfers will reduce income inequality and improve social welfare, as measured by a Benthamite social welfare function. This is because utility functions are concave with respect to income. However, concavity of the utility function with respect to income in all three goods is not sufficient to establish that income redistribution improves population health.

**Proposition 8** Implementing an income redistribution policy using lump-sum taxes and transfers increases population health as long as $\frac{\partial^2 F}{\partial M^2} > \delta \frac{\partial^2 X}{\partial M^2}$.

**Proof.** See Appendix. ■

A utility-maximizing individual rationally chooses to overeat. And whereas rich people consume more food than the poor, they are also able to invest more resources in exercise and thus achieve a better balance between caloric intake and caloric expenditure. Income redistribution consequently improves population health only when the adverse health effect of reduced income for the rich is less than the improvement in health status due to the increased income of the poor. This requires that the demand for exercise increase more rapidly with income than the demand for food. If the condition is satisfied this result therefore provides clear support to the claim that under certain circumstances incomes policies are also public health policies. Income redistribution improves both average health and social welfare. However if the condition is not satisfied, then it is possible that income redistribution will in fact reduce population health *even if individual utility is concave in income.* Thus the result also underscores that anti-poverty programs do not always lead to an improvement in population health, since a policy that reduces the income inequality might be detrimental to the overall health status of the community.

### 2.4.2 Using tax policy to maximize population health

There has been considerable public controversy around proposals to use tax policy to encourage individuals to make healthier life-style choices. Proponents of the 'fat tax', for example, argue that applying higher taxes to fast food meals will encourage consumers to choose more nutritious food. Public health officials do not hesitate to strongly advocate in favour of public policies which will improve population health. However, they do not necessarily pay attention to the economic costs of pursuing the maximization of population health to the exclusion of any other objectives. The analysis below investigates both the feasibility and desirability of using fiscal policy instruments to persuade citizens to adopt a healthy lifestyle. The policy experiment considered here imposes a lump-sum tax $T$ on individual income and subsidizes exercise at rate $\tau$, setting the tax/subsidy rates to ensure budget balance, that is:

$$T = \tau\, \tilde{X}(\tau, T) \tag{2.39}$$

Since the tax policy aims to maximize health, from equations (2.25) and (2.26) we require that $H_F = H_X = 0$. Thus the first-order conditions of a rational individual under such tax policy will require:

$$X \;:\; \gamma\,(p_x - \tau) = 0 \tag{2.40}$$

$$F \;:\; HV_F - \gamma p_f = 0 \tag{2.41}$$

$$S \;:\; HV_S - \gamma p_s = 0 \tag{2.42}$$

$$\gamma \; : \; p_f F + (p_x - \tau) X + p_s S = M - T \tag{2.43}$$

It is immediately evident, from equation (2.40), that a policy which maximizes population health must be one that fully subsidizes exercise, so that the marginal cost to the individual is zero. Observe that since $\gamma > 0$, the per unit subsidy to exercise must be equal to price of exercise itself. Otherwise, it will be impossible to achieve the objective of maximizing population health.[26]

Secondly, it should be noted that a health-maximizing fiscal policy cannot be implemented unless all citizens have adequate income. Recall that for those people whose income is lower than the threshold income level, $\frac{b}{2c}p_f$, health maximization choices are not affordable. When tax policy is applied to persuade individuals to adopt a healthy-life style, the lowest income level for which it is feasible to implement such a tax policy is weakly greater than $\frac{b}{2c}p_f$.

Thirdly, although tax instruments can be used to pursue the maximization of population health, the increase in population health is achieved only at considerable cost in terms of social welfare. The proof is straightforward. Denote a solution $\left(\tilde{F}, \tilde{X}, \tilde{S}\right)$ as the individual's consumption bundle under the tax policy. Since $\tau = p_x$,we know:

$$p_f * \tilde{F} + p_s * \tilde{S} = M - p_x * \tilde{X} = M - \tau * \tilde{X} = M - T$$

The solution $\left(\tilde{F}, \tilde{X}, \tilde{S}\right)$ is always affordable for a utility maximizing individual who is not subject to the health-maximizing tax policy. By revealed preference, it is clear that the health maximizing outcome is less preferred. Consequently, implementing a policy that

[26] Notice that taxes on foods alone cannot induce individuals to make healthy life choices. In this model, the only way to persuade individuals to exercise optimally is by fully-refunding their expenditure on exercise.

leads to population health maximization will generally decrease social welfare. This fact provides some insight into the difficulties of formulating public policy which appropriately weighs the importance of public health and individual welfare considerations.

## 2.5 Conclusion and Discussion

In this chapter a simple representative agent model is developed in which utility is scaled by health status. We assume that the higher health status an individual has, the better she can enjoy life. Health, in this context, is an indicator of an individual's wellness, depending only on nutrition (food) and exercise. The model casts light on several key phenomena. First it clearly shows that rational individuals will overeat and underexercise compared to the choices of health maximization.[27] Second it demonstrates that wealthier people make healthier choices simply because they have the means to do so: health is a "normal" good. Policies which increase income will lead individuals to have higher welfare and better health.

Based on the simple model developed in this chapter we extend the analysis on the policy perspective.[28] Under certain circumstances, we show that a policy which redistributes income from high to low-income individuals can both increase the average level of social welfare ("happiness") in the economy and population health. Nevertheless, no amount of income will induce individuals to make health-maximizing choices. If policy

[27] This chapter presents a model in which health is only a component of an individual's utility function. Thus the individual does not simultaneously maximize health and happiness (utility).

[28] This paper has established a benchmark case for policy analysis. In the model we assume that all individuals are identical and are seeking life happiness given a particular budget constraint. Social welfare here corresponds to the welfare of an average individual.

makers are only concerned about health, then exercise must be fully subsidized. Any tax on food cannot, by itself, lead to the right combination of exercise and food. Significantly, however, the pursuit of a healthy population is seen to have a cost in terms of social welfare as compared to using incomes policies.

Another important insight from this chapter concerns what might be called the impact of abject poverty. In our representative agent model, affordability is not generally an issue, since there exist an infinite number of combinations (little food with small amounts of exercise or lots of food with much exercise) that maximize health. But there exists an income level below which it is impossible for individuals to choose even the least-cost healthy combination. For those individuals, fully-subsidized exercise will not be enough to ensure an optimal food-exercise combination: their income has to be increased.

Our model could be fruitfully enriched by developing the health production function in a number of directions. One interesting extension would differentiate individuals by initial health endowments and then examine what happens when, for instance, income changes. Or health-care services could be added into the health production function. One could also posit a more sophisticated relationship between wealth and health, for example by allowing health status to affect future earnings opportunities.[29]

[29] Another possible extension to the model is to introduce mutliple goods. For example, assume there are two kinds of foods: one represets a high quality and expensive food $F_1$,and the other a low quality but cheap food $F_2$. Both of them enter into the health production function: $H = b(\alpha_1 F_1 + \alpha_2 F_2 - \delta X) - c(\alpha_1 F_1 + \alpha_2 F_2 - \delta X)^2$ where $\alpha_1 < \alpha_2$, indicates that more calories accrue from consuming one unit of the lower quality of food. Similar results are obtained with this formulation. At the utility maximization point, individuals overeat both goods and underexercise. Moreover the only effective way to induce a healthy lifestye is to fully subsidy exercise. Clearly, there is lots of opportunity to develop more sophisticated models of the determination of nutritional status with multiple food goods.

In conclusion, economists can make an important contribution to the public health policy debate: public health is clearly not simply an issue for medical professionals. Most importantly, public policies that target income also affect health. Consequently, in designing government fiscal policies, it may be important to consider how adjustments to these policies may affect individual health outcomes. Understanding the link between wealth and health is critical to the successful implementation of policy instruments.

## 2.A Appendix

Recall that the second-order condition for a regular local maximum requires:

$$| \bar{H} | = \begin{vmatrix} 0 & -p_f & -p_x & -1 \\ -p_f & a_{11} & a_{12} & a_{13} \\ -px & a_{21} & a_{22} & a_{23} \\ -1 & a_{31} & a_{32} & a_{33} \end{vmatrix} < 0$$

Also we assume $V_{FS} > 0$.

**Proof of Proposition 3**

Substitute equations (2.33) to (2.38) into the expression for $\frac{dF}{dM}$ to obtain:

$$\begin{aligned} | \bar{H} | * \frac{dF}{dM} &= a_{23}^2 p_f - a_{22}a_{33}p_f - a_{13}a_{23}p_x + a_{12}a_{33}p_x + a_{13}a_{22}p_s - a_{12}a_{23}p_s \\ &= p_x\delta H H_F V_{FS} V_S + p_x \delta H_F^2 V_S^2 - p_x \delta H H_{FF} V V_{SS} \\ &\quad -p_x \delta H H_F V_F V_{SS} + p_s \delta^2 H H_{FF} V V_{FS} + p_f \delta^2 H_F^2 V_S^2 \\ &\quad -p_s \delta^2 H_F^2 V_F V_S - p_f \delta^2 H H_{FF} V V_{SS} \end{aligned}$$

Since

$$p_x \delta H_F^2 V_S^2 + p_f \delta^2 H_F^2 V_S^2 - p_s \delta^2 H_F^2 V_F V_S$$

$$= p_x\delta^2 H_F^2 V_S^2 + p_f\delta^2 H_F^2 V_S^2 - \delta^2 H_F^2(p_f + \frac{p_x}{\delta})V_S^2 = 0$$

Then

$$\begin{aligned} | \bar{H} | * \frac{dF}{dM} &= p_x\delta H H_F V_{FS} V_S - p_x\delta H H_{FF} V V_{SS} - p_x\delta H H_F V_F V_{SS} \\ &+ p_s\delta^2 H H_{FF} V V_{FS} - p_f\delta^2 H H_{FF} V V_{SS} \end{aligned}$$

Since

$$H_F < 0, | \bar{H} | < 0, V_{FS} > 0$$

we have

$$\frac{dF}{dM} > 0$$

Similarly, substitute equations (2.33) to (2.38) into the expression for $\frac{dX}{dM}$ to obtain:

$$\begin{aligned} | \bar{H} | * \frac{dX}{dM} &= p_x H^2 V_{FS}^2 + 2P_x H H_F V_{FS} V_S + p_x H_F^2 V_S^2 - p_x H H_{FF} V V_{SS} \\ &-2p_x H H_F V_F V_{SS} - p_x H^2 V_{FS}^2 + \delta p_s H H_{FF} V V_{FS} \\ &+\delta p_s H H_F V_F V_{FS} - \delta p_s H_F^2 V_F V_S - \delta p_s H H_F V_{FF} V_S \\ &+\delta p_f H H_F V_{FS} V_S + \delta p_f H_F^2 V_S^2 \\ &-\delta p_f H H_{FF} V V_{SS} - \delta p_f H H_F V_F V_{SS} \end{aligned}$$

Since

$$p_x H^2 V_{FS}^2 - p_x H H_{FF} V V_{SS} < 0$$

and

$$\begin{aligned} & p_x H_F^2 V_S^2 + p_s\delta p_f H_F^2 V_S^2 - p_s\delta H_F^2 V_F V_S \\ = \; & p_x H_F^2 V_S^2 + \delta p_f H_F^2 V_S^2 - \delta H_F^2(p_f + \frac{p_x}{\delta})V_S^2 = 0 \end{aligned}$$

we have:

$$
\begin{aligned}
\mid \bar{H} \mid * \frac{dX}{dM} &< 2p_x H H_F V_{FS} V_S - 2p_x H H_F V_F V_{SS} - p_x H^2 V_{FS}^2 \\
&+\delta p_s H H_{FF} V V_{FS} + \delta p_s H H_F V_F V_{FS} - \delta p_s H H_F V_{FF} V_S \\
&+\delta p_f H H_F V_{FS} V_S - \delta p_f H H_{FF} V V_{SS} - \delta p_f H H_F V_F V_{SS} \\
&< 0
\end{aligned}
$$

Since

$$H_F < 0, \mid \bar{H} \mid < 0, V_{FS} > 0$$

we have

$$\frac{dX}{dM} > 0$$

In the same way we have:

$$
\begin{aligned}
\mid \bar{H} \mid * \frac{dS}{dM} &= \delta p_x H H_{FF} V V_{FS} + \delta p_x H H_F V_F V_{FS} - \delta p_x H_F^2 V_F V_S \\
&-\delta p_x H H_F V_S V_{FF} + \delta^2 p_s H_F^2 V_F^2 - \delta^2 p_s H H_{FF} V V_{FF} \\
&+\delta^2 p_f H H_{FF} V V_{FS} - \delta^2 p_f H_F^2 V_F V_S
\end{aligned}
$$

Since

$$-\delta p_x H_F^2 V_F V_S + \delta^2 p_s H_F^2 V_F^2 - \delta^2 p_f H_F^2 V_F V_S = 0$$

we get:

$$
\begin{aligned}
\mid \bar{H} \mid * \frac{dS}{dM} &= \delta p_x H H_{FF} V V_{FS} + \delta^2 p_f H H_{FF} V V_{FS} + \delta p_x H H_F V_F V_{FS} \\
&-\delta p_x H H_F V_S V_{FF} - \delta^2 p_s H H_{FF} V V_{FF} \\
&< 0
\end{aligned}
$$

Since

$$H_F < 0, \mid \bar{H} \mid < 0, V_{FS} > 0$$

we have

$$\frac{dS}{dM} > 0$$

**Proof of Proposition 4**

$$\begin{aligned}
\frac{dH}{dM} &= H_F\left(\frac{dF}{dM} - \delta\frac{dX}{dM}\right) \\
&= \frac{H_F}{\mid \bar{H} \mid}\left[\begin{array}{c} \left(\begin{array}{c} a_{23}^2 p_f - a_{22}a_{33}p_f - a_{13}a_{23}p_x + a_{12}a_{33}p_x \\ +a_{13}a_{22}p_s - a_{12}a_{23}p_s \end{array}\right) \\ -\delta\left(\begin{array}{c} -a_{23}a_{13}p_f + a_{12}a_{33}p_f + a_{13}^2 p_x - a_{11}a_{33}p_x \\ -a_{13}a_{12}p_s + a_{11}a_{23}p_s \end{array}\right) \end{array}\right] \\
&= \frac{H_F}{\mid \bar{H} \mid}\left[\begin{array}{c} -p_x\delta H^2 V_{FS}^2 + p_x\delta H^2 V_{FF}V_{SS} - p_x\delta H H_F V_S V_{FS} \\ +p_x\delta H H_F V_F V_{SS} - p_s\delta^2 H H_F V_F V_{FS} + p_s\delta^2 H H_F V_{FF} V_S \\ -\delta^2 H H_F p_f V_{FS} V_S + \delta^2 H H_F p_f V_F V_{SS} \end{array}\right]
\end{aligned}$$

By assumption we know that

$$V_{FF}V_{SS} > V_{FS}^2,\ V_{FS} > 0$$

Thus we have:

$$\begin{aligned}
\mathrm{Si}\,gn\left(\frac{dH}{dM}\right) &= \mathrm{Si}\,gn\left[\begin{array}{c} -p_x\delta H^2 V_{FS}^2 + p_x\delta H^2 V_{FF}V_{SS} - p_x\delta H H_F V_S V_{FS} \\ +p_x\delta H H_F V_F V_{SS} - p_s\delta^2 H H_F V_F V_{FS} \\ +p_s\delta^2 H H_F V_{FF} V_S \\ -\delta^2 H H_F p_f V_{FS} V_S + \delta^2 H H_F p_f V_F V_{SS} \end{array}\right] \\
&> 0
\end{aligned}$$

**Proof of Proposition 5**

Using Cramer's Rule we have:

$$\begin{aligned}
\frac{dF}{dp_f}\left|\bar{H}\right| &= -F\left(\begin{array}{c} a_{23}^2 p_f - a_{22}a_{33}p_f - a_{13}a_{23}p_x \\ +a_{12}a_{33}p_x + a_{13}a_{22}p_s - a_{12}a_{23}p_s \end{array}\right) \\
&\quad -a_{33}p_x + 2a_{23}p_x\, p_s\lambda - a_{22}p_s^2\lambda > 0
\end{aligned}$$

$$\begin{aligned}
\frac{dS}{dp_s}\left|\bar{H}\right| &= -S\left(\begin{array}{c} a_{22}a_{13}p_f - a_{12}a_{23}p_f - a_{12}a_{13}p_x \\ +a_{11}a_{23}p_x + a_{12}^2 p_s - a_{11}a_{22}p_s \end{array}\right) \\
& \quad -a_{22}p_f^2\lambda + 2a_{12}p_f\, p_x\lambda - a_{11}p_x^2\lambda \\
&> 0
\end{aligned}$$

$$\begin{aligned}
\frac{dX}{dp_x}\left|\bar{H}\right| &= -X\left(\begin{array}{c} -a_{23}a_{13}p_f + a_{12}a_{33}p_f + a_{13}^2 p_x \\ -a_{11}a_{33}p_x - a_{13}a_{12}p_s + a_{11}a_{23}p_s \end{array}\right) \\
& \quad -a_{33}p_f^2\lambda + 2a_{13}p_f\, p_s\lambda - a_{11}p_s^2\lambda
\end{aligned}$$

Given that $\left|\bar{H}\right| < 0$ we have

$$\frac{dF}{dp_f} < 0, \frac{dS}{dp_s} < 0$$

Substitute equation (2.32) into the expression for $\frac{dX}{dp_x}\left|\bar{H}\right|$, we have

$$\begin{aligned}
& -a_{33}p_f^2\lambda + 2a_{13}p_f\, p_s\lambda - a_{11}p_s^2\lambda \\
&= \lambda\left(-a_{33}p_f^2 + 2a_{13}p_f\, p_s - a_{11}p_s^2\right) \\
&= \lambda\left(\begin{array}{c} -HV_{SS}p_f^2 + 2H_F V_S p_f p_s + 2HV_{FS}p_f p_s - H_{FF}Vp_S^2 \\ -2H_F V_F p_s^2 - HV_{FF}p_S^2 \end{array}\right) \\
&= \lambda\left(\begin{array}{c} -HV_{SS}p_f^2 - \frac{2}{\delta}H_F V_S p_s p_x + 2HV_{FS}p_f p_s - \\ H_{FF}Vp_S^2 - 2H_F V_F p_s^2 \end{array}\right) > 0
\end{aligned}$$

Thus

$$\frac{dX}{dp_x} < 0$$

**Proof of Proposition 6**

Using Cramer's Rule it is straightforward to show that:

$$\frac{dF}{dp_x}\left|\bar{H}\right| = -X\left(\begin{array}{c} a_{23}^2 p_f - a_{22}a_{33}p_f - a_{13}a_{23}p_x \\ +a_{12}a_{33}p_x + a_{13}a_{22}p_s - a_{12}a_{23}p_s \end{array}\right)$$

$$+a_{33}p_f\,p_x\lambda - a_{23}p_f\,p_s\lambda - a_{13}p_x\,p_s\lambda + a_{12}p_s^2\lambda$$

$$\frac{dF}{dp_s}\left|\bar{H}\right| = -S\left(\begin{array}{c} a_{23}^2p_f - a_{22}a_{33}p_f - a_{13}a_{23}p_x \\ +a_{12}a_{33}p_x + a_{13}a_{22}p_s - a_{12}a_{23}p_s \end{array}\right)$$

$$+a_{22}p_f\,p_s\lambda - a_{23}p_fp_x\lambda - a_{12}p_sp_x\lambda + a_{13}p_x^2\lambda$$

$$\frac{dX}{dp_f}\left|\bar{H}\right| = -F\left(\begin{array}{c} -a_{23}a_{13}p_f + a_{12}a_{33}p_f + a_{13}^2p_x \\ -a_{11}a_{33}p_x - a_{13}a_{12}p_s + a_{11}a_{23}p_s \end{array}\right)$$

$$+a_{33}p_fp_x\lambda - a_{23}p_f\,p_s\lambda - a_{13}p_xp_s\lambda + a_{12}p_s^2\lambda$$

$$\frac{dX}{dp_s}\left|\bar{H}\right| = -S\left(\begin{array}{c} -a_{23}a_{13}p_f + a_{12}a_{33}p_f + a_{13}^2p_x \\ -a_{11}a_{33}p_x - a_{13}a_{12}p_s + a_{11}a_{23}p_s \end{array}\right)$$

$$+a_{23}p_f^2\lambda - a_{12}p_f\,p_s\lambda - a_{13}p_fp_s\lambda + a_{11}p_xp_s\lambda$$

$$\frac{dS}{dp_f}\left|\bar{H}\right| = -F\left(\begin{array}{c} a_{22}a_{13}p_f - a_{12}a_{23}p_f - a_{12}a_{13}p_x \\ +a_{11}a_{23}p_x + a_{12}^2p_s - a_{11}a_{22}p_s \end{array}\right)$$

$$+a_{22}p_fp_s\lambda - a_{23}p_f\,p_x\lambda - a_{12}p_sp_x\lambda + a_{13}p_x^2\lambda$$

$$\frac{dS}{dp_x}\left|\bar{H}\right| = -X\left(\begin{array}{c} a_{22}a_{13}p_f - a_{12}a_{23}p_f - a_{12}a_{13}p_x \\ +a_{11}a_{23}p_x + a_{12}^2p_s - a_{11}a_{22}p_s \end{array}\right)$$

$$+a_{23}p_f^2\lambda - a_{12}p_f\,p_s\lambda - a_{13}p_fp_x\lambda + a_{11}p_sp_x\lambda$$

In each of above equations, the first term on the right hand side is positive, while the summation of all the other terms could be either positive or negative. Thus the signs for all the cross price effects are ambiguous.

**Proof of Proposition 7**

Using Cramer's Rule it is straightforward to show:

$$\begin{aligned}\mid \bar{H} \mid * \frac{dF}{d\delta} &= -p_xp_sHVV_{FS}\left(H_F - \delta XH_{FF}\right) + p_fp_xHVV_{SS}\left(H_F - \delta XH_{FF}\right) \\ &\quad -2p_xp_sH_F^2VV_S + p_x^2HH_FV_{FS}V_SX - p_x^2HH_{FF}VV_{SS}X \\ &\quad -p_x^2HH_FV_FV_{SS}X - \delta p_sH_FH_{FF}V^2\end{aligned}$$

As long as $H_F > \delta H_{FF}X$, i.e., the elasticity of the marginal benefit on health with respect to exercise is greater than 1, $\left(\frac{\partial H_X}{\partial X}\frac{X}{H_X} < -1\right)$, all the terms on the right hand side of the equations are negative, and thus we have

$$\frac{dF}{d\delta} > 0$$

$$\begin{aligned}
\mid \bar{H} \mid * \frac{dX}{d\delta} &= -p_s^2 H_F H_{FF} V^2 - 2p_s^2 H_F^2 V V_F - p_s^2 H V V_{FF}(H_F - \delta H_{FF}X) \\
&+2p_f p_s H V V_{FS}(H_F - \delta H_{FF}X) - p_f^2 H V V_{SS}(H_F - \delta H_{FF}X) \\
&+2p_f p_s H_F^2 V V_S - p_x p_s H H_{FF} V V_{FS} X \\
&-p_x p_s H H_F V_F V_{FS} X + p_x p_s H H_F V_{FF} V_S X - p_f p_x H H_F V_s V_{FS} X \\
&+p_f p_x H H_{FF} V V_{SS} X + p_f p_s H H_F V_F V_{SS} X \\
&+\delta p_x p_s H H_{FF} V V_{FS} X - \delta p_f p_x H H_{FF} V V_{SS} X
\end{aligned}$$

With the assumptions $V_{fs} > 0$ and $\frac{\partial H_X}{\partial X}\frac{X}{H_X} < -1$, all except the first two terms on the right hand side are positive. However further judgements cannot be conducted and the sign of $\frac{dX}{d\delta}$ remains ambiguous.

The expression of $\frac{dS}{d\delta}$ could be simplified as follows:

$$\begin{aligned}
\mid \bar{H} \mid * \frac{dS}{d\delta} &= p_x p_s H_F H_{FF} V^2 + 2p_x p_s H_F^2 V V_F + p_x p_s H H_F V V_{FF} \\
&-p_f p_x H H_F V V_{FS} + p_x^2 H H_{FF} V V_{FS} X + p_x^2 H H_F V_F V_{FS} X \\
&-p_x^2 H_F^2 V_F V_S X - p_x^2 H H_F V_S V_{FF} X + \delta p_f p_s H_F H_{FF} V^2 \\
&+\delta p_x p_s H_F^2 V_F^2 X - \delta p_x p_s H H_{FF} V V_{FF} X + \delta p_f p_x H H_{FF} V V_{FS} X \\
&+\delta p_f p_x H_F^2 V_F V_S X
\end{aligned}$$

The sign of $\frac{dS}{d\delta}$ still remains ambiguous.

$$\begin{aligned}
\frac{dH}{d\delta} &= H_F * (\frac{dF}{d\delta} - \delta\frac{dX}{d\delta}) \\
&= \frac{H_F}{|\bar{H}|} * \left[\begin{array}{c} (p_f p_x HVV_{SS} - p_x p_s HVV_{FS})\,(H_F - \delta X H_{FF}) \\ +p_x^2 HH_F V_{FS} V_S X - p_x^2 HH_{FF} VV_{SS} X - p_x^2 HH_F V_F V_{SS} X \\ -\delta \left(\begin{array}{c} -p_x p_s HH_{FF} VV_{FS} X - p_x p_s HH_F V_F V_{FS} X \\ +p_x p_s HH_F V_{FF} V_S X - p_f p_x HH_F V_s V_{FS} X \\ +p_f p_x HH_{FF} VV_{SS} X + p_f p_x HH_F V_F V_{SS} X \\ (-p_s^2 HVV_{FF} + 2p_f p_s HVV_{FS})(H_F - \delta H_{FF} X) \\ -p_f^2 HVV_{SS}(H_F - \delta H_{FF} X)) \end{array}\right) \end{array}\right] \\
&< 0
\end{aligned}$$

Thus as long as $\left|\frac{\partial H_X}{\partial X}\frac{X}{H_X}\right| > 1$, i.e., $H_F > \delta H_{FF} X$, we have

$$\frac{dH}{d\delta} < 0$$

**Proof of Proposition 8**

We assume population health is measured by average population health. Previous results have shown that:

$$\frac{dH}{dM} = H_F\frac{\partial F}{\partial M} + H_X\frac{\partial X}{\partial M} = H_F\left(\frac{dF}{dM} - \delta\frac{dX}{dM}\right) > 0$$

Then

$$\frac{d^2H}{dM^2} = -2c\left(\frac{dF}{dM} - \delta\frac{dF}{dM}\right)^2 + H_F\left(\frac{d^2F}{dM^2} - \delta\frac{d^2X}{dM^2}\right)$$

With the condition that $\frac{\partial^2 F}{\partial M^2} > \delta\frac{\partial^2 X}{\partial M^2}$, we know that population health is concave in income, thus income redistribution will definitely improve overall population health.

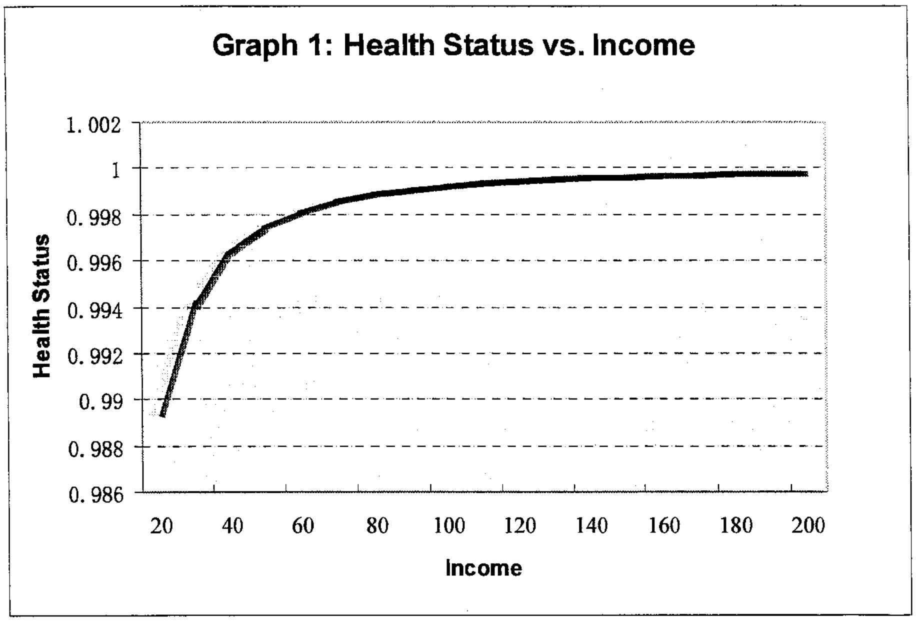


**Table A1 Simulation Results**

| $p_f = 0.5, p_x = 0.8, p_s = 0.4, \delta = 0.1, M \in [20, 200]$ | | | | |
|---|---|---|---|---|
| $M$ | $F$ | $X$ | $S$ | $H$ |
| 20 | 1.130345696 | 0.2736879097 | 48.03969206 | 0.989395758 |
| 30 | 1.514422338 | 4.372011347 | 64.36294938 | 0.994036887 |
| 40 | 1.901687711 | 8.400581327 | 80.82172771 | 0.996201796 |
| 50 | 2.290580848 | 12.39354394 | 97.34968606 | 0.99737585 |
| 60 | 2.680410105 | 16.36602896 | 113.9174295 | 0.998080928 |
| 70 | 3.070825146 | 20.32569993 | 130.5100687 | 0.998536543 |
| 80 | 3.461630388 | 24.27683527 | 147.1192915 | 0.998847611 |
| 90 | 3.852708322 | 28.22200546 | 163.7401037 | 0.999069276 |
| 100 | 4.243984198 | 32.16284568 | 180.3693284 | 0.99923273 |
| 110 | 4.635408238 | 36.1004448 | 197.0048501 | 0.99935668 |
| 120 | 5.026946034 | 40.03555551 | 213.6452064 | 0.999452887 |
| 130 | 5.418573048 | 43.96871458 | 230.2893545 | 0.999529045 |
| 140 | 5.810271317 | 47.90031494 | 246.936531 | 0.999590346 |
| 150 | 6.202027391 | 51.83065082 | 263.5861641 | 0.999640433 |
| 160 | 6.593831 | 55.75994687 | 280.2378175 | 0.99968187 |
| 170 | 6.985674169 | 59.68837754 | 296.8911522 | 0.999716535 |
| 180 | 7.377550612 | 63.61608036 | 313.545901 | 0.999745832 |
| 190 | 7.769455304 | 67.54316522 | 330.2018504 | 0.999770823 |
| 200 | 8.161384186 | 71.46972093 | 346.8588279 | 0.999792286 |

# Chapter 3
# An Empirical Investigation of Household Income and Income Policies on Obesity in Canada

## 3.1 Introduction

Obesity is of growing concern throughout the Western world. In Canada, obesity rates amongst adults and children have increased at an alarming rate over the past couple of decades. According to Katzmarzyk (2002), the national prevalence of obesity more than doubled in the 13-year span from 1985 to 1998, from 5.6% in 1985 to 14.8% in 1998. The 2004 Canadian Community Health Survey, which reports measured height and weight, also reveals a notable increase in obesity among adolescents and adults in almost every age group compared to those reported in 1978/79 (Shields 2005, Tjepkema 2005). Obesity in adults is linked to greater health risks, including the increased incidence of hypertension, coronary disease and type-2 diabetes. It also increases the risk of several types of cancer, gallbladder disease, musculoskeletal disorders, and respiratory problems. Clearly, obesity-related chronic conditions will have an impact on the future health status of the population and the economic burden of illness.

Obesity is not only a substantial risk factor for individual health and well-being, but also a major public finance issue. The epidemic prevalence of obesity has a very high economic cost. In addition to the disease burden on individuals, it is estimated that Canadian governments spend about $2 billion per year, or 2.4% of the total health-care budget, on prevention and treatment of obesity (Kurscheid and Lauterback 1998, Seidell 1995). These costs provide strong motivation for developing new policies and programs to combat obesity.

Effective policies to combat obesity require an understanding of the many causes of obesity. Obesity has long been considered as a "health problem". Medical researchers have gained a good understanding of the biological and genetic factors underlying this condition (Bray *et al.* 1998, WHO 1998). However, we know that the root causes of obesity are much larger than these, and that socio-economic factors may be playing an important role: spending more hours at sedentary work leaving fewer hours for exercise and fewer hours for meal preparation, commuting to work by car rather than walking or walking to public transport, and so on (Chou *et al.* 2004, Cutler *et al.* 2003, Philipson 2001). Moreover, individuals' lifestyle choices depend critically on their budget constraints. People with greater means can afford to join health clubs and purchase higher quality food, enabling them to better control their intake of calories, and compensate for their less physically demanding working environment.

Although it is well-recognized that socioeconomic status may be a crucial factor influencing lifestyle choices, much of the research that has been undertaken to date – mainly by medical researchers and epidemiologists – has focussed on the *correlation* between socioeconomic factors and weight, neglecting the analysis of why individuals become obese. Moreover, correlation analysis is quite unsatisfactory when it comes to trying to determining causality. To gain greater insight into the role that socio-economic factors play in determining obesity requires the application of more sophisticated econometric techniques and, of course, access to appropriate data.

This chapter employs the Canadian Community Health Survey (CCHS) to carefully estimate the role of income and wealth in determining obesity.[30] The precise mechanism by which income influences obesity has received inadequate attention in the literature. We pay close attention to the possibility that obesity has the potential to affect individuals' occupational choice, resulting in obese people earning lower incomes. This research also looks at the channels through which income may affect obesity. The CCHS data set allows us to examine two transmission mechanisms underlying this relationship, namely nutrition and leisure time physical activities. The data analysis provides support for the view that one of the reasons for which wealthier individuals are healthier is simply because they can in fact afford to spend more on better food and leisure time physical activity.

Another contribution of this chapter is its analysis of how incomes policies[31] may influence obesity. We investigate whether Fraser Mustard's well-known claim[32] that an income policy is a health policy holds true when it comes to obesity. Typically, governments in the Western world perceive income policies almost exclusively as a tool for combatting poverty and income inequality. This chapter attempts to measure the health consequences of incomes policies with respect to obesity. Such calculations are particularly significant in the Canadian context, in which both health care and social welfare expenditures fall largely upon the public sector: if reduced spending on income assistance programs leads

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[30] I am extremely grateful to the Statistics Canada Tom Symons Research Fellowship Program which facilitated my access to this confidential data set as well as providing financial support for this research project.

[31] Income policies in this chapter refer to polices such as income insurance or maintenance policies.

[32] See, for instance, Flower 1997.

to a higher incidence of obesity and therefore rising health care costs, then the overall impact on the Government's budgetary position may not be as anticipated. The analysis of two significant income policies shows that both policies do have a measurable impact on health outcomes, particularly for low income individuals.

## 3.2 Literature Review

An impressive body of literature exists that examines the determinants of health outcomes, including obesity. This chapter focuses on the growing contribution made by researchers employing econometric techniques to discern the relationship between income and health. To this end, the relevant papers for this study are classified into three groups: those that examine health and income, those that examine the effect of income on obesity, and those that examine how obesity influences income[33].

Much of the health literature focuses on correlations between income and different health outcomes. The problem with correlation is that it does not imply causality. As a result, several researchers have employed econometric techniques in an effort to discern causality between income and health outcomes, in particular, examine any potential endogeneity between income and health. Four papers are notable in this regard. Ettner (1996) explicitly recognizes the causality issue and employs appropriate techniques to deal with this problem. Cross-sectional data sets from the United States are used to examine the structural impact of income on a host of health indicators including self-assessed health status, number of days in bed, alcohol consumption, and symptoms of depression. Et-

[33] Appendix B provides a table which synthesizes the related empirical literature.

tner employs an instrumental variables technique to account for the possible endogeneity between income and health. Four instruments are used: parent's education, spouse's education, the state unemployment rate, and years of work experience. She finds that increased income significantly improves health outcomes, both physically and mentally. Meer, Miller and Rosen (2003) also examine the causal link between health and wealth. Using the four waves of the Panel Study of Income Dynamics, they deal with the problem of endogeneity by using inheritance as an instrument variable for changes in wealth. Their results are consistent with the findings of earlier studies: changes in wealth are strongly *associated* with changes in health. However despite the large estimated coefficients for wealth obtained by implementing the instrumental variables strategy, the estimated coefficients are not significantly different from zero. Consequently, the authors conclude that changes in wealth will not *affect* health, at least in the short-run.

Dooley and Stewart (2004) use the Canadian National Longitudinal Survey of Children and Youth to look at the relationship between income and the cognitive ability of children. In this case endogeneity between income and the health outcome is less likely to be a problem because the target group is children. They correct for family and child-specific fixed effects and find that income is still likely to have a positive impact on cognitive outcomes. Buckley, Denton, Robb and Spencer (2004) examine whether income and education are causally linked to health status as people age. They use the Canadian Survey of Labour Income Dynamics, and draw a sample of individuals aged 50 and above who report being in good health in 1994. They are then able to track the relationship between income and health for this group over the 1996 and 1998 SLID surveys. By focusing on individuals in good health in 1994, these researchers are able to avoid the potential causality between health and income. They find clear evidence that family income and educational background positively affect the health outcome of older individuals.

The second and third groups of papers deal specifically with obesity - the health indicator of focus in this chapter.[34] Let us begin with the larger of these two groups of papers, namely those that examine how income affects obesity. By far the most comprehensive study looking at the determinants of obesity is Chou, Grossman and Saffer (2004) who employ a huge US data set with over one million observations. Because of the sheer size of their data set, they can employ a simple Ordinary Least Squares technique to estimate the determinants of an individual's body-mass index (BMI)[35], and a linear probability model to estimate the probability of being obese. This paper is able to include a wide variety of explanatory variables: in addition to household and personal characteristics, it controls for the per-capita number of fast-food restaurants in each state, the prices of meals in restaurants and at home, as well as the prices of cigarettes and alcohol. Once all of these factors are taken into account, they still find that household income has a negative effect on obesity, although this effect falls as income increases. However, the authors do not explicitly correct for the problem of causality in their regression analysis.

Lakdawalla and Philipson (2002) test how technological change, which has led to more sedentary lifestyles and lower food prices, leads to an increase in the avoirdupois of

[34] Two papers provide excellent reviews of studies looking at the relationship between socioeconomic status (SES) and obesity. Sobal and Stunkard (1989) review 144 published studies in both developed and developing societies in the past 40 years. More recently, Ball and Crawford (2005) conduct an updated review of 34 papers and focus specifically on relationship of SES to weight change.

[35] The body-mass index is defined as weight in kilograms divided by height in meters squared (kg/m$^2$). See the appendix A for a detailed explanation.

the US working population. They find that whereas the relationship between weight and income has an inverted U-shape for male workers, with the downturn starting at the fourth income quartile, there is a consistently negative relationship between BMI and income for female workers. Ruhm (2000) examines the impact of macroeconomic conditions on obesity. Using an aggregate data set spanning the 50 states from 1972 to 1991, he looks at how unemployment rates and median family incomes affect average BMI. Ruhm finds that an increase in the unemployment rate is associated with a reduction in BMI, but family income is not a statistically significant determinant of body weight. Zhang and Wang (2004) also investigate the relationship between socio-economic conditions and obesity. They look at the concentration of obesity across income groups stratified by various characteristics. They find a stronger link between socio-economic status and obesity in women than in men: higher income is more often associated with less obesity for women than is the case for men.

Several papers consider the impact of household income on the obesity of children and adolescents; causality is less likely to be a concern in this context.[36] Goodman, Slap and Huang (2003), using US data, find that lower household income and lower parental education are both associated with increased obesity and depression amongst adolescents. By contrast, Gordon *et al.* (2003), using the same data set, reach the conclusion that these two characteristics play only a limited role in explaining overweight teenagers. Working with Australian data, Wang, Patterson and Hills (2002) find a negative relationship between household income and obesity in children. Finally, Nayga (2000) tries to explain obesity

[36] Again it should be noted that sick children could result in lower family income if parents have to take time off work to care for the children.

as a function not only of personal and household characteristics, but also of indicators that capture the health knowledge of individuals. He finds that health awareness is inversely related to the probability that an individual is obese, and that income is not a statistically significant determinant of obesity.

A final group of papers examines how obesity or physical attributes affect personal or family income, rather than *vice versa*. Women are more likely than men to be penalized on the earnings front due to an unattractive physical appearance. This earnings penalty is also affected by ethnicity. Averett and Korenman (1996) use the US National Longitudinal Survey of Youth (NLSY) to investigate the relationship between BMI and family income, hourly wage, and the probability of marriage. They find that obese women tend to have lower family income than other women; this is because obese women have a lower probability of being married and hence have lower spousal income. The findings for men are weaker and mixed. Pagan and Davila (1997) use the 1989 NLSY. They find that women pay a penalty for being obese whereas men do not. Mitra (2001), employing the 1993 NLSY, also finds support for the view that physical attributes affect the wages of women but not those of men. Finally, Cawley (2004) runs more comprehensive earnings equations, using the 1981-2000 NLSY, and finds that excess body weight consistently lowers wage rates for white women, but heavier black women tend to earn more than their lighter counterparts.

In sum, research findings indicate that richer individuals tend to be less overweight, and overweight white females typically belong to lower-income households, *ceteris paribus*. In the analysis that follows, we pay special attention to this causality problem, especially as it plays out across men and women, in order to discern how income is affecting obesity among Canadian adults.

## 3.3 Data Set and Descriptive Statistics

The data for this analysis are drawn from the master files of the Canadian Community Health Survey (CCHS) collected by Statistics Canada. The CCHS targets individuals aged 12 and older who are living in private dwellings, and collects information on respondent's health status, health care utilization and health determinants. The sample is representative of the Canadian population.[37]

The CCHS is a cross-sectional survey that is conducted every two years since 2000. There are two cycles in each survey: the first year cycle, denoted by ".1", is a general population survey which collects information at the health region level; the second cycle, denoted by ".2", is a smaller survey designed to collect information on specific health issues at the provincial level. This chapter draws on the data collected in cycle 1.1 and cycle 2.1. Data collection began in September 2000 and in January 2003, respectively, for these two surveys, and each was conducted over a 12 month period. Each survey samples over 130,000 households, covering all provinces and territories across Canada. One or two respondents are randomly selected from each sampled household.

The CCHS contains information on height and weight, from which each respondent's body-mass index (BMI) may be calculated. It also contains detailed information on a wide

[37] For detailed information about the CCHS see the Statistics Canada's website: http://www.statcan.ca/english/concepts/health/

range of socio-demographic variables. Moreover, the CCHS collects data on diet and nutrition, as well as on physical activities undertaken on a typical work day and during leisure time. This information allows us to examine a variety of channels via which income may influence obesity. Finally, the large size of the data set renders it ideal for the examination of the relationship between obesity and income.

The two cycles of the survey are pooled together to increase the sample size.[38] Household incomes are measured in constant 2000 dollars. Since more interviews were conducted by telephone in cycle 2.1 than cycle 1.1 (70% versus 50%), there may be a "mode effect" on self-reported height and weight. That is, changes in the method of data collection may affect the comparability of the health indictors (St-Pierre and Béland 2004). However, an analysis of the mean of BMI and frequency of obesity did not reveal any significant differences between the two cycles. Moreover, including a dummy variable indicating the cycle difference in the regressions does not affect the results in most cases.[39]

The analysis of this paper is restricted to adults aged 18 to 64. The BMI scale is an appropriate health indicator for individuals in this age group, and household income is a reasonable indicator of wealth.[40] Individuals attending school full-time are excluded from the sample as their household income is not particularly informative. We also exclude individuals living in the Yukon, Nunavut, or the Northwest Territories, since persons in these regions are mostly aboriginal peoples who have very different lifestyles from other

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[38] Regressions were also conducted on cycle 1 only with comparable results to those arising with the pooled data.

[39] The dummy variable is only significant at the 5% level for the OLS regression on the BMI for men.

[40] Although permanent income is a better indicator of wealth than a single year of income (Curtis *et. al* 2001), this information is not available due to the cross-sectional nature of the data set.

Canadians and not all required data are available from the territories. In addition, so as to obtain a reliable health index related to body weight, height and health, pregnant women, lactating women, and individuals measuring less than three feet or more than seven feet are excluded.

Our estimating sample consists of 57,813 men and 59,336 women. Throughout this paper, the data are weighted by the sample weights provided by Statistics Canada to ensure that the sample reflects the Canadian population. Table1 defines all the variables used in this chapter, and table 2 provides the descriptive statistics of the variables. The ubiquity of weight problems is clearly seen from the BMI data for adult Canadians. The mean of BMI for both men and women is over 25 - the threshold level to be considered overweight. Moreover, one in six adult Canadians is obese – considered as a BMI of 30 or more. The mean BMI for adult men is higher than for adult women, as is the rate of obesity. Note that reported average household income is high compared to the population as a whole; this is because our sample consists mainly of working-age individuals. Measured in year 2000 dollars, men report an average household income of $70,600 while women report $62,007. Both of them report an average household size of three persons.

Most demographic characteristics are similar between men and women in the sample. On average individuals are 42 years of age. More than 70% of the population is married or living in a common-law relationship. Over 65% of individuals are living in census metropolitan areas (CMAs) defined as the urbanized core with a population of at least 100,000. The data set reports the ethnic origins of the respondents: 7% are originally from Asian countries, while around 1.5% are black. The numbers of individuals with

Latin American or Aboriginal roots are smaller, each accounting for less than 1% of the total sample. Individuals from other origins or with more than one origin account for about 1.8% of the whole sample. New immigrants (five years or less since arrival) and recent immigrants (five to ten years since arrival) respectively account for over 2% of the population. The education levels of men and women are also very close, though a greater proportion of women reported having terminated their education with a high school or college diploma, while a greater proportion of men obtained a university degree.

Table 2 nonetheless reveals that living habits and lifestyle choices are quite different across the genders. More men than women drink heavily and smoke regularly. Over one fifth of individuals face some difficulties that restrict their activities, and that number is higher among women. With respect to physical activities during a typical day, more women than men report having to stand as a part of their usual activities. However men are more frequently required to lift or carry loads, especially very heavy loads. Women tend to be more frequent consumers of fruits and vegetables. On average 44% of women have more than five servings of fruits and vegetables per day, while the comparable number for men is only 30%. Men appear to be more active in their leisure time physical activities in comparison to women, and more men exercise regularly than do women.

## 3.4 Econometric Model and Analytical Framework

Chapter 2 presented a theoretical model of the relationship between health and wealth. In this chapter, we use body weight as an indicator of health, and household income to represent wealth. The following simple model characterizes an individual's choices and provides a theoretical basis for an econometric framework. An individual's utility is a function of his/her health status $H$, consumption of private goods contributing to health $X_H$, and of private goods not related to health $X_{NH}$. Individuals maximize their utility functions by choosing $X_H$ and $X_{NH}$ knowing the technological relationship between health status $H$ and their consumption of $X_H$, and subject to a standard budget constraint:

$$\underset{X_H, X_{NH}}{Max} \; U\left(H, X_H, X_{NH}\right) \tag{3.44}$$

where

$$H = g(X_h| \, Z) \tag{3.45}$$

$$Y = p_H \, X_H + p_{NH} \, X_{NH} \tag{3.46}$$

Solving this problem for the optimal values of private consumption $X^*_{NH}$ and $X^*_H$, and then substituting into the health production function yields

$$H = f\left(p, Y \mid Z\right)$$

where $Z$ represents a vector of exogenous individual characteristics. We can thus express the health status of the individual as a function of income as well as of the prices of the private consumption goods given a host of personal characteristics. For the purposes of this empirical work, the weight-related health indictors for any individual $i$ in a reduced form model is expressed as:

$$WEIGHT\ INDICATOR_i = Z_i * \beta + Y_i * \alpha + \varepsilon_i. \tag{3.47}$$

This chapter looks at two weight-related health indictors: one is the body mass index (BMI), a continuous variable, and the other is obesity, a binary variable which takes the value 1 if an individual's BMI is 30 or higher and the value 0 otherwise.[41] The BMI equations are estimated using an ordinary least squares (OLS) procedure, while a probit model is used to examine the probability of being obese.

Income plays a key role in the analysis. We have chosen household income rather than individual income because it is the former that is typically more important for the household budget constraint and hence influences the ability of any one household member to purchase private goods. Besides the natural logarithm of household income, five categories of variables are included as determinants of body weight. The first category includes personal and household characteristics including age and age squared, the number of household members, marital status, whether or not the household contains children, and highest personal education level. Geographic factors, such as whether or not the individual lives in a CMA and his or her region of residence, are in the second group. The third group of factors includes ethnicity and immigration status, while the fourth group includes lifestyle choices such as drinking and smoking habits. The fifth category includes variables describing the nature of the respondent's daily routine, such as whether their work entails a lot of sitting, standing, carrying light loads, or carrying heavy loads. We have also controlled for whether or not the respondent has any problems that would restrict their mobility, and their usual hours of work per week.

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[41] A very low BMI might also indicate poor health. However, underweight people only represent about 2% of the sample. Excluding these observations does not make any difference to the regression results.

Existing studies of the relationship between socioeconomic status and obesity reveal an inconsistent pattern across men and women. In view of this fact, tests are conducted to see if the estimated coefficients for the male and female samples are statistically different from each other. We interacted the male dummy variable with all other explanatory variables and ran the full model with these interactive terms. F-statistics were constructed for the OLS equations, and likelihood- ratio tests for the probit equations, enabling us to examine whether all of estimated coefficients on the interactive terms were simultaneously equal to zero. In both cases, this hypothesis was rejected at the 1% significance level. We also ran the pooled (men and women) regression including an interactive term with gender and income. The estimated coefficient on this interactive term also proved to be statistically significant. In view of these results, the analysis of this chapter disaggregates the sample by gender.

In the modelling framework introduced earlier in this chapter income is assumed to be exogenously rather than endogenously determined; as such, income is assumed to play a causal role in determining health status. A richer framework takes a human capital approach to earnings, explicitly recognizing that earnings are a function of many individual and household characteristics, potentially including body weight. We first estimate the model assuming income to be exogenous and present the conventional regression results in the first columns of the results tables. We then re-estimate the model using a two-stage instrumental variables technique to correct the endogeneity associated with income (we detail below the instruments that are used). In the first stage, we estimate household income, and this estimate is then used in the second stage estimation of BMI (or obesity).

The resulting estimated coefficients are presented in the tables beside the conventional results. Robust standard errors (White 1980) are used to calculate the relevant t and F statistics for the linear regressions.[42]

If income is endogenously determined, the IV estimation procedure offers consistent estimates of the structural effect of income on body weight, conditional on the validity of the instruments employed. Otherwise, the conventional regression results may be more accurate. Hausman specification tests are conducted for this purpose. The residuals generated in the first stage are included as a covariate in the second stage regression and their significance is tested. The tests are conducted separately for men and for women for both the BMI and probit regressions. There are thus four cases in total. The Hausman test results indicate that the null hypothesis that income is exogenous cannot be rejected for the probit equations for men, but can be rejected for all of the other three cases. In other words, except for the male probits, the IV estimates should be preferred to the conventional regression results.

Another issue of concern to this analysis is the validity of the instruments. An ideal instrument is related to household income, but is not related to an individual's body weight outcome other than through income. Four different instruments are considered in this chapter: the highest level of education for the household, dwelling characteristics, the unemployment rate by health region, and whether interest and dividends are part of the individual's household income. The CCHS does not provide information on the education level

[42] Statistics Canada has produced 500 bootstrap weights for the combined CCHS (cycle 1.1 and cycle 2.1). The bootstrap method is used to take into account sample design information. Regression results using the 500 bootstrap weights change the significance levels of a few variables.

of the spouse or parents (which is used by Ettner (1996)) but does offer information on the highest education level in the household. Whether the dwelling is owned by one household member and the number of bedrooms in the dwelling are also available in this survey. The unemployment rate is a factor influencing the wage rate. Data on the unemployment rate are reported by health region for the population 15 years of age and over, derived from the Labour Force Survey and reported in the CANSIM tables.[43] Interest and dividend income, which is related to household income but not so related to the body weight outcome, is provided by the CCHS.

The first stage regression results from the IV procedure and related validity tests on the instruments in both two stages are presented in Appendix C. These results confirm that all of the proposed IVs are highly correlated with household income. The robust F-statistics associated with the hypothesis that the estimated coefficients on each group of instruments are jointly zero far exceeds 10, the minimum level suggested by Staiger and Stock (1997), and satisfy the first necessary condition for suitable IV estimates, the "relevance" condition. To verify that the instruments are not correlated with BMI or obesity directly, as is required if they are to be suitable IVs, we follow the spirit of the Ettner (1996) and perform a series of diagnostic tests in the second stage regressions. We include one group of instruments at a time in the second-stage regression, and test whether the coefficients on the instruments are different from zero both independently and jointly. F and t tests are again conducted for the BMI linear regressions, and likelihood ratio tests for the probit regressions on obesity. The test results, presented in the third and fourth panel of Appendix C, reveal that most of the

[43] These data were retrieved from CANSIM tables 109-5004 and 109-5204.

instruments do not belong in the second stage regressions. The estimated coefficients on highest household education level and the unemployment rate are not significantly different from zero in the second-stage equations. Although these tests show that the number of bedrooms and dividend income are not perfect instruments, overall the tests support the conclusion that these instruments are not correlated with an individual's body weight. Thus the "exogeneity" condition is satisfied. We are consequently reasonably confident of the validity of the instruments and rely on them to derive consistent estimates of the effect of income on body weight.

A final issue worth noting is the mechanism through which income affects the body weight outcome. The reduced-form model outlined in equation (3.47) implies that income affects BMI or obesity through the individual's ability to consume goods $X_H$ that will contribute to an individual's health. These private goods may be considered the "pathways" through which income influences obesity. The CCHS data set allows us to examine two important pathways: nutrition (proxied by the consumption of vegetables and fruits) and exercise (proxied by leisure-time physical activities). We introduce these pathways into the reduced-form regression model and examine the extent to which nutrition and exercise account for the effect of income. In addition, we look at how income influences the amount of each of these "goods" consumed and thus whether food and exercise are normal goods.

## 3.5 Empirical Results

We first discuss the regression results from the reduced-form model excluding the pathways, and then look at what happens when the pathways are explicitly introduced into the model.

### 3.5.1 Empirical results from the reduced form regression

As previously discussed, both conventional and IV regression analysis are undertaken to explain BMI and obesity. The determinants of the body-mass index (BMI) are examined using an OLS procedure corrected for heteroskedasticity, while the obesity decision is examined using a probit procedure. The sample is disaggregated by gender. We begin by discussing non-income variables, and then turn back to income, the main focus of our analysis.

Tables 3 and 4 present the conventional OLS and IV estimates on BMI for men and women, respectively, while the probit results by gender are reported in tables 5 and 6. To interpret the coefficients from the probit regressions, we calculate the probability of being obese for a reference man or women, and then report by how much this reference probability would change in response to a change in one of the underlying characteristics. Table 7 defines the reference individual and presents these probability impacts.[44] For factors other

[44] The reference male or female essentially embodies the average value of all continuous characteristics, or the predominant characteristic for the dichotomous variables. So, he or she is 42 years of age, lives in a household of size three, has a college diploma or certificate, is white, born in Canada, and lives in a census metropolitan area in Ontario. He works 21 hours per week, while she works 15 hours per week, he or she is a regular drinker, never smokes, does not have any activity restrictions, and works at a sedentary occupation. His or her dwelling is owned, has three bedrooms, has no income from dividends or interest, and lives in a health region with an unemployment rate of 7.34%.

than income, the estimates from the conventional and IV regressions are very similar. As such, unless otherwise noted, the discussion refers to all of the aforementioned tables and focuses on the IV estimates.

**Personal and household characteristics (except income)**

By looking across tables 3 through 6, it is clear that both the BMI and probability of obesity rises with age but at a decreasing rate, which corresponds well to findings reported elsewhere (e.g., Lakadawalla and Philipson, 2002). For instance, a man (women) aged 20 is 33% (37%) less likely to be obese in comparison to his (her) 42 year old counterpart. Interestingly, as ages rises, we find that its impact on obesity becomes negative, with the probability of being obese peaking between 50 and 60 years of age.

Marital status generally has a positive impact on BMI and obesity. Although estimates on BMI suggest that the impact of this variable is higher for women (0.6685) than for men (0.5889), the probit results show that marriage has a larger impact on male girth than females'. An unmarried man has a probability of being obese which is 12.5% lower than his married counterpart, while the probability of obesity for an unmarried woman would be 8.6% lower. One explanation for this result is that obese and overweight women are less likely to marry (or remain married), while the same is not true for their male counterparts.[45]

The size of the household also matters. For men, one more child adds 0.085 to his average BMI, while for women it adds 0.329 to her BMI. This result makes sense,

[45] To test if marital status is an endogenous factor, Hausman specification tests are conducted. Results of the tests reject the hypothesis that marital status is endogenous.

especially when one considers that the primary way of increasing household size is through children, and the bearing of children often has a lingering impact on the body weight of women. Interestingly, the impact of children on the probability of being obese is negative: as compared to our reference individual, probability of being obese increases by 16% for both men and women were there no children in the family. This may suggest that children force parents to engage in activities which they may otherwise eschew – going to the park, picking up toys, and so on. Thus, while they may get heavier, they do not become as obese as childless individuals.

The level of education is a key factor when it comes to body weight. The regression results display a clear inverse relationship between the level of education and both BMI and obesity. A more educated individual has a lower expected BMI and a lower probability of being obese. From table 7 we see that if our reference man is university educated rather than a college graduate, his probability of being obese falls by 30%, whereas if he did not complete high school, this probability is 13.5% higher. Feinstein (1993) suggests that education strongly influences individuals' activities – like exercise and food intake – which directly determine health outcomes. Nayga (2000) shows that education has a negative impact on excess body-weight through its effect on health knowledge: once knowledge is controlled for, the impact of education disappears.

**Geographic and Ethnic Factors**

Living in a census metropolitan area (CMA) consistently has a negative impact on BMI and obesity. One explanation is the presence of more opportunities for walking in the urban environment. Alternatively, such an environment may render individuals more susceptible to peer-pressure regarding body shape. The region of residence in Canada also matters. Compared to Ontario residents, individuals living in British Columbia and Quebec are lighter, while those in Atlantic Canada are heavier. Prairie men and women are comparable to their Ontario counterparts. Some regional differences might be explained by climate, which influences individuals' abilities to undertake outdoor activities, or by local "culture" such as cuisine.

A number of researchers have highlighted the important role played by ethnicity in determining obesity.[46] Our analysis controls for whether the individual is Asian, black, Aboriginal, Latin, or of some other origin. These ethnic variables appear to have a heterogenous impact on body weight. Individuals of Asian origin have a consistently lower BMI in comparison to whites, while those of Aboriginal origin have a consistently higher BMI – a pattern that also holds when we examine the probability of being obese. These results are very consistent with those of Tremblay *et al.* (2005). Differences are observed across the genders when it comes to black individuals: black men have lower BMIs and a lower probability of being obese compared with white men, black women are heavier than white women, *ceteris paribus*, but they are less likely to be obese.

There is a recent literature which suggests that new immigrants are healthier than average representatives of their ethnic group and healthier, on average, than the population of their host country (McDonald and Kennedy (2004), Deri (2005)). Over time, however, this "healthy immigrant" effect seems to disappear. McDonald and Kennedy (2004) use

[46] See, for instance, Zhang and Wang (2004), Chou, Grossman and Saffer (2004) for analysis on United States, and the recent published paper by Tremblay *et al.*(2005) in Canadian context.

Canadian data to confirm the existence of this effect. We include dummy variables denoting whether or not the individual is a new (less than five years since arrival), medium-term (five to ten years since arrival) or long-term immigrant (over ten years since arrival) and find that the most recent immigrants have the lowest BMI followed by medium-term immigrants, suggesting, indeed, that immigrants, over time become closer to the reference population from the point of view of weight. Deri (2005) finds a similar result. The same pattern persists when it comes to the probability of being obese for men – it rises with length of time in the country. However, for women, medium-term immigrants seem to have the lowest probability of being obese.

**Addictive Life Habits and Physical Activities**

The literature recognizes that smoking and excessive alcohol consumption have detrimental effects on health(U.S. DHHS 1964, WHO 2000). We include dummy variables denoting whether the individual is currently a heavy drinker or smoker, or once had such habits (see table 1 for detailed definitions). Men who are currently or formerly heavy drinkers tend to have higher BMI, while women who are heavy drinkers tend to have lower BMI. One explanation may be that the types of drinks consumed by men are heavier in calories than those consumed by women. However, only males who are former drinkers have a higher probability of being obese relative to all others, while for women current drinkers are less likely to be obese, *ceteris paribus*. The impact of smoking is very similar across men and women. Smokers tend to have lower BMI and lower probabilities of obesity, everything else constant. This result is not surprising. The stimulants in cigarettes promote weight loss, and cigarette smoking often substitutes for snacking.

The regression results with respect to physical activities are all quite sensible. Men and women with mobility problems have higher BMIs and obesity probabilities. While the number of hours usually worked has no effect on weight, the type of work undertaken matters a lot. People who have to stand or walk a lot and those who have to lift light or heavy loads all have lower BMIs and lower probabilities of being obese relative to those in sedentary occupations. For instance, were our sedentary reference male (female) to be occupied in a position requiring light work, his (her) probability of being obese would fall by 23% (29%), whereas were he (she) to occupy a position with heavy lifting, his (her) probability would fall by 20% (16%).

**Income**

We now turn to the important question of how income affects BMI and obesity. Income here refers to the respondents' best estimated total household income before tax and deductions in the past 12 months.[47] Results from the Hausman specification tests suggest that income is endogenous for women, while the income of men seems to be independent of the probability that they will be obese. This finding is consistent with the conclusions of the three papers previously mentioned which found that the body weight of women affects their earnings but not that of men (Pagan and Davila (1997), Mitra (2001) and Cawley

[47] About 10% of observations either did not report their household income exactly, or did not provide any information of income. We examined whether the exclusion of these observations made any material difference to the regression results by predicting the household income of these individuals and including their predicted incomes in the analysis. We found that the inclusion of these missing observations had little effect on the regression results. We therefore report the results for the sample for which self-reported household income is available and exclude those households where this information is unavailable.

(2004)). If higher income leads to lower BMI or obesity rates, and if a better body shape leads to higher income, then conventional OLS estimates will overestimate the income effect on the body weight outcome. For women we find the opposite results, namely that the magnitude of the income effect increases rather than decreases from the conventional to the IV regression. It is not clear why this is the case; however this pattern is consistent with the findings of Ettner (1996) and Meer, Miller and Rosen (2003) who also employ the IV technique to deal with the potential endogeneity between income and health outcomes.

From tables 3 and 4 we see that, for men, although income has a positive association with BMI, its effect is not statistically significant. If income is indeed exogenous for men, we find that income will not influence the probability of being obese among men. The results are different for women. The conventional results indicate that income is negatively related to BMI and, more importantly, the IV estimations indicate an even stronger effect from income to body weight. This negative relationship between income and weight is also found in the model of obesity for women.

Table 8 provides an overview of the income effects estimated from the BMI and obesity regressions. To interpret the coefficients, we present the implied elasticities from the OLS procedures and the change in the relative risk of obesity from the probit procedures. At the weighted sample mean, the income elasticity of BMI for men is small (0.005) and positive using the conventional regression results, whereas the estimated coefficient on income in the male IV regressions is statistically insignificant. The BMI of women is much more responsive to income compared to that of men. At the sample mean, the income elasticity of BMI is -0.069 from the IV regression. These results are quite different from that of

Chou, Grossman and Saffer (2004), which pools both men and women, and reports -0.03 as the elasticity.

The impact of income on the probability of being obese is not clear for men. From table 8, the conventional regression results for men imply that income does not significantly influence the possibility of being obese. However the IV estimate indicates that an increase of a half unit of log income from the mean value (from 70,600 to 116,400) will decrease the relative risk of obesity by 5% for men. As compared to the impact on BMI, the impact of income on the probability of being obese is more substantial for women. At the sample mean, an increase of one half a unit in log income (from 62,007 to 102,232) will decrease the risk of obesity for women by as much as 24% as interpreted by the IV regression results. These findings accord with those of Zhang and Wang (2004) who report a stronger link between the socio-economic status of women and obesity in comparison to that of men.

To further explore how income affects obesity, we looked at how changing income in some meaningful way would affect the probability of being obese for men and women. We began by adjusting the reported household income by household size using the 40/30 equivalence scale, and the resulting adjusted income was then divided into quartiles.[48] Once the quartiles were established, we used the respondents' reported household incomes as the appropriate income for the analysis. In table 9, "low" income refers to individuals in the first quartile; "high" income refers to individuals in the fourth quartile, while "mid-

[48] Appendix A provides a detailed explanation as to how the income quartiles are derived. The idea here is that this equivalent income has taken into account household size, and thus all individuals in each quartile are comparable from an income perspective. Once individuals are categorized into quartiles based on this equivalent income measure, their reported household income is then used in the ensuing analysis.

dle" combines the second and third quartile of the income distribution.[49] We then asked the question: what would happen if an individual's household income were increased by \$2,350 (10% of the mean of the low-income group), by \$4,700 (20% of the mean of the low-income group) and by \$7,050 (30% of the mean of the low-income group).

The impact on male obesity from the income increases is presented using the IV estimates. This is not very informative given that the underlying estimated coefficients on income are statistically weak. For women, the story is different. Adding \$2,350 income to low-income women decreases their probability of being obese by 4%, decreases the middle-income group's probability by 2% and the high-income group's by 1%. Doubling this change in income approximately doubles the effect. This sort of exercise clearly demonstrates the impact of income redistribution on obesity. For instance, taking \$2,350 from a high-income woman and giving it to a low-income woman would increase the former's chances of being obese by 1% while it would reduce the latter's by 4%. The impact on the total population would be even larger given that the number of low-income women (28.44% of total women population ) is much larger than the number of high-income women (21.64% of total women population). Moreover, taking the income from a man would have no statistical effect on his weight, while giving it to a woman would also decrease the obesity rate of total population. We discuss such policy effects in more detail in the next section.

[49] Low-income cutoffs (LICOs) and median income are alternative methods to measure low income and poverty. But both of then only provide rough information on high-income people. The equivalent scale method enables us to identify the high-income group and thus better facilitates the simulations on income redistribution.

### 3.5.2 Pathway effects

The model described in equation (3.47) is a reduced-form model: the estimated coefficient on income $Y$ embodies the effects from the consumption of all health-related private goods. With higher levels of income, individuals are able to consume more health-related goods and thus obtain better health outcomes. These health-related goods can be thought of as pathways through which income influences health – in this case, body weight. The CCHS provides information on individuals' consumption of fruits and vegetables and leisure time physical activities. Thus, two pathways are examined: the "nutrition" pathway which relies on the consumption of fruits and vegetables, and the "exercise" pathway which entails leisure time physical activities. We introduce two continuous variables reflecting these pathways into the regression model, and examine how they influence the estimated coefficients on income. If income influences the consumption of these two goods, which in turn affect an individual's body weight, we would expect a reduction in the magnitude of the income coefficient.[50]

The reduced form models are re-estimated including measures of nutrition and exercise, and the results are presented in tables 3-1 to 6-1. For comparison purposes, table 10 summarizes the coefficients estimated for the two pathways and for income. Comparing the estimates on income to those reported in table 8 when nutrition and exercise are excluded, we find that the estimated coefficient on income does change. However this change

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[50] As indicated in Dooley and Stewart (2004), a change in the income coefficient when the pathways are included could also result from having some unobserved characteristics which are correlated with all the three: two consumption goods, income, and body weight outcomes. Thus, the new estimated coefficient on income as a result of including the pathways might not reflect its true impact on body weight.

should be interpreted carefully, as most of the estimates are not statistically significant for the male sample.

The direction of change of the income coefficients are all as expected– the impact of income on healthy body weight outcome becomes smaller when the pathways are controlled, indicating that some of the effect of income on body weight is actually via the purchase of better nutrition and exercise. The magnitude of change in the estimated coefficients of income measures how much the effect of income might be accounted for by the two consumption pathways. However, given that income is not a statistically significant factor influencing the body weight of men, we cannot say very much about any changes in its estimated coefficient for men. Using the estimated coefficients from the female sample, we find that the combination effect of the two pathways account for some 15% of the effect of income on BMI, and about 5% of its effect on the probability of obesity among women.

The fact that the estimated coefficients on income for the female sample remain statistically significant after controlling for nutrition and exercise supports the observation made in chapter 2, namely that affordability does not seem to be the only (or indeed, the main) link between income and health. Other reasons may explain the different health outcomes between the poor and the rich. For example, poor people usually live in a poor community and may lack access to fresh fruits or good exercise facilities.

Finally we look at how "nutrition", measured as the number of daily servings of fruits and vegetables, and "exercise", measured as the metabolic value of monthly leisure exercise, affect body weight outcomes directly. Table 10 shows that more exercise significantly reduces BMI and the probability of obesity for both men and women, and more servings of fruits and vegetables help reduce obesity among women as well. Nutrition, however, does not significantly affect the body weight of men. This result may simply be an artifact of the way in which the nutrition variable is constructed by the CCHS, as it is reported as the *number of times* rather than the *total amount* of any fruits and vegetables consumed.

It is instructive to begin by looking at the nutrition and exercise habits of individuals by income group. We define as "healthy eaters" those who are frequent fruit and vegetable consumers, consuming no fewer than five servings daily. Active exercisers are those whose metabolic energy expenditure index for leisure time physical activities is no less than three.[51] Graphs 2 and 3 present the percentage of healthy eaters and active exercisers by income quartile, respectively.

Taking the lowest income group as the reference group, we see that the percentage rate in the other income groups increases by income group. This means that people in the higher income groups are more likely to develop healthy eating and exercise regularly in comparison to those in the lowest income group. Although the frequency of healthy eaters is not significantly different across the middle two groups, the increasing trend is clearly shown in graph 2. On average the frequency of healthy eaters increases by 10% for men and 18% for women when moving from the lowest income group to the highest income group. Exercise displays an even stronger trend over income groups: people in the highest income group are 60% more likely to exercise compared to those in the lowest income

[51] According to Canada's *Food Guide,* individuals should consume between five and ten servings of vegetables and fruits per day. A metabolic energy expenditure value of 3 is equivalent to, for example, an hour of walking, or a half an hour of basketball every day. This "active" threshold level is defined by the CCHS.

group. Interestingly, these two graphs show that women are more likely to be a heathy eaters, while men are more likely to be active exercisers.

When talking about exercise, we are only including leisure activities but not the physical nature of an individual's work. The occupations of low income people usually require more physical activities than those in the higher-income groups, and thus may reduce their incentives to pursue exercise in leisure time. Regressions are conducted respectively for vegetable and fruits servings and exercise participation which control for these sorts of factors. Table 11 presents the regression results when the daily consumption of fruits and vegetables is the dependent variable, and table 12 presents the results when the number of monthly leisure time physical activities participation is the dependent variable.[52] All the t-statistics reported are based on robust standard errors (White 1980). The predictions stemming from these results are presented in graph 4 and 5. The data are presented on a monthly basis.

The regression results show that higher income is consistently associated with the more frequent consumption of fruits and vegetables and of more exercise participation.[53] We use the estimated coefficients from these regressions to predict obesity prevalence for different income levels based on a reference group as before. As household income increases, the number of servings of fruits and vegetables increase, *ceteris paribus* as shown in graph 4. The same positive relationship exists between leisure time exercise participa-

[52] To facilitate the interpretation of the coefficient estimates and predictions, the total number of monthly exercise activities lasting at least 15 minutes, rather than the metabolic energy expenditure value, is used as the dependent variable for the exercise regression.

[53] As the main interest of analysis here is whether or not healthy eating and exercise are normal goods, we focus on the sign rather than the magnitude of the regression estimates on income.

tion and household income, as shown in graph 5. The graphs to some extent show that both nutrition and exercise are normal goods.

## 3.6 Simulations: Health effect of Incomes Policies

Incomes policies are widely employed by governments to decrease income inequality, combat poverty, or promote efficiency in the labour market. Sweeping welfare reforms, implemented both federally and provincially during the 1990s, had a significant impact on the incomes of segments of the Canadian population. Not surprisingly, analysis of these policies focuses on the direct impact on redistribution of household income, and to a less extent on the labour market; the impact of income policy redistribution on health outcomes has been essentially ignored. Yet to the extent that income is a determinant of health, then it is evident that income policies are also potentially health policies, and it may be important to take impact on health outcomes into account when designing optimal income policies. This section addresses this issue by examining the impact of two different incomes policies on one specific health outcome, namely, the probability of being obese, using the results from existing studies with respect to the effect on income of various policies and the estimates from the previous econometric analysis. Obviously, to the extent that income affects health outcomes other than obesity, this simulation exercise clearly understates the health impact of income policy reforms.

In this section the impact of two different income policies is considered: provincial social assistance and the child-support system. Several researchers have examined the impact of social assistance on the income and income distribution in Canada. Dyck (2003) examines how fiscal redistribution evolved during the fiscal consolidation period from 1994 to 2000. Using 1997 data she calculates that families in the lowest income quartile would lose an average of roughly 10% of their income if the provincial social assistance program were abolished. Below, we show that provincial social assistance programs also markedly reduce the incidence of obesity amongst women. Separately, we consider the impact of the child-support reforms on the income – and therefore on the health – of separated custodial parents. Again, the analysis clearly shows that child support policy has important consequences not merely for the distribution of income and reduction of poverty, but also for population health.

**Policy I: Welfare policy**

In this simulation exercise we consider a reform in social assistance that increases the household income of women in the lowest income group by 10%. Two scenarios for financing the reform are considered: in the first, the increased tax burden is borne entirely by high income taxpayers; in the second, the reform is financed by middle income earners. Table 13 presents the results from the simulation. The first panel describes the population before the policy reform. The number of individuals in each income group is indicated in the first row. For an average person in each group, his or her probability of being obese is shown in the second row, and the total number of people who are obese is reported in the third.

The policy reform increases the household income of women in the lowest income group by 10%, i.e., $2350 on average for each household. If the additional expenditure is financed by raising taxes on high-income earners, both men and women, then taxes increase by 1.36% (or, on average, \$1764) for this group. Alternatively, if middle-income earners are expected to finance the additional redistribution, then this reduces after-tax income by 1.36% (or, on average, \$816) for these taxpayers.[54] Based on the IV coefficients from the estimation presented in tables 5 and 6, we calculate how the probability of being obese changes for an average person in each group, both in absolute and relative values. As shown in the second panel of table 13, this policy reform results in a 4.8% decrease in the probability of low income women being obese. If the reform is financed by the highest income group, the probability of being obese increases by 0.96% for women and 0.15% for men in the highest income group. If the policy reform is financed by middle income taxpayers instead, there will be an increase of 0.83% and 0.14% in the probability of being obese for middle-income women and men respectively.

Using the above calculations, we can determine the reduction in the number of obese individuals as a result of the income policy reform. These results are presented in the penultimate row in table 13. The final row of table 13 expresses these numbers in percentage terms: As the result of the policy reform, the total number of obese women decreases by 2.2% if the policy initiative is financed by increasing taxes on the highest income group, or by 1.98% if middle income earners bear the financial burden. Significantly, the tax reform has essentially no impact on the incidence of obesity amongst men. These calculations therefore suggest strongly that income policies have a measurable impact on this particu-

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[54] The tax rate is similar between high-income and middle-income groups due to the larger number of population in the later group. The numbers are derived according to the population distributions:

high-income group: $\frac{2350*19952}{15316+11251} = 1764$; $\frac{2350*19952}{129583*26567} = 1.361\%$

middle-income group: $\frac{2350*19952}{28956+28533} = 816$; $\frac{2350*19952}{59874*57489} = 1.362\%$.

Note we impose a tax on both male and female high-income earners; the administrative cost of the tax is not included in this simulation.

lar health outcome. To get a clearer picture of the overall impact of social assistance on health outcomes it would be necessary to undertake similar calculations with respect to other health indicators which appear to be linked to income, such as depressive symptoms.

**Policy II: Child-support policy**

Lone mothers accounts for 21% of the low-income women in our data. Among lone mothers over 51% of them are in the lowest-income group. In households headed by a lone mother, child support payments generally constitute a large share of the household income. And whereas the important role of child support policy on the distribution of income is widely recognized, it is clear that child support also will have an impact on health outcomes. Barham and Devlin (2003) consider a typical separating household in which both the custodial parent (assumed to be the mother) and the non-custodial parent are low-income earners. Barham and Devlin's data shows that a typical low-income custodial parent is between 30-35 years of age and earns \$19,149 in year 2000. The correspondent non-custodial parent's income is \$28,600. Given the non-custodial parent's income, the custodial parent will receive \$5,136 in the form of child-support payments, increasing the income of the custodial household by 26.8%.

To determine the health impact of the child support payment, we consider the impact of an increase in income of \$5,136 on a representative custodial parent, that is a woman, age 35, non-married, with children, and in the lowest income group. To finance the child support payment, we decrease the income of a representative non-custodial parent, that is, a man, age 35, non-married, with no children, and in the middle- income group. Table 14 presents the result of the simulation. Using the coefficients from the earlier estimation, it is found that, before payment of child support, the probability of being obese for the woman and for the man is 18.73%, and 14.43% respectively. Once child support is taken into account, the probability that a single mother is obese decreases by 2.25%. Or equivalently, the risk of a single mother being obese is reduced by 12.02% as a result of the payment of child support. Importantly, the payment of child support does not have any measurable impact on the likelihood that a non-custodial parent will be obese.

These results therefore indicate that child support policy – which is generally construed as an income policy – also has a measurable impact on at least one important health outcome. Child support policy is in effect also a health policy. It must again be underscored that obesity is only one specific health outcome that is affected by income, and so the overall health improvement of single mothers benefiting from adequate child support is not fully captured by the calculations. But this simulation exercise does strongly suggest that the impact of child support on health outcomes should be taken into account by policy makers when considering any reforms to our existing child support system.

## 3.7 Conclusions and Policy Implications

This chapter employs the 2000-01 and 2003 Canadian Community Health Surveys to ascertain the link, if any, between income and body weight. The empirical analysis pays careful attention to the possibility that income may affect body weight, and also that body weight may affect income. The issue of causality is examined with the aid of Hausman specification tests, and the model is estimated using instrumental variables. Interestingly, we find that causality is a more serious problem for women than is the case for men: specifically, obesity in men does not affect their income while obesity in women does. For both sexes, BMI affects income.

The empirical results indicate that income is an important determinant of body weight for women. An increase of one half of a unit in log income (from 62,070 to 102,336) decreases the risk of obesity by almost one fourth among women. Adding $2,350 income to low-income women decreases their probability of being obese by 4%. The results for men are ambiguous and more difficult to interpret because the IV and conventional least squared regression analysis results yield inconsistent estimated coefficients for the income variable. Moreover, even if the coefficient on the income variable is statistically significant, the estimated coefficient is numerically small which means that the impact on BMI or obesity of changing income is very modest.

Before concluding that income is an insignificant determinant of body weight for men, we looked at how income may affect weight indirectly through its impact on exercise and nutrition. Exercise and nutrition constitute two channels by which income may indirectly affect body weight. Analysis of the data shows that both exercise and nutrition are normal goods: consumers with higher incomes consume more fruits and vegetables, and participate in leisure time exercise more frequently. By including measures of exercise and nutrition in the regression analysis it is possible to determine the role played by these two variables on body weight. More importantly, the indirect income effect (that is, the effect through these pathways) on body weight can be examined by comparing the estimated coefficient on income for the expanded model to the estimate from the reduced-form model with no pathways. We find that the inclusion of the pathways seems to affect the link between income and body weight for women but not for men, as the estimated coefficients on income for men are statistically insignificant. Furthermore, exercise, quite sensibly, reduces the obesity of men and women, while nutrition reduces the BMI of women, but has no effect on men.

The results with respect to exercise and nutrition lead to two policy implications. Firstly, income still affects the body-weight of women even when the pathways are included in the analysis. This suggests that the link between income and body weight is not solely a question of affordability. Whereas it is often suggested that a lack of financial means may explain why poorer individuals tend to be more obese than their richer counterparts, this observation indicates that affordability is not the whole story. Secondly, our results suggest that exercise has a healthy effect on body weight for both men and women. Thus policies that promote exercise may be quite effective in the battle of the bulge. Moreover, although income may not have a direct effect on male body weight, increased income does increase men's participation in leisure time physical activities, which in turn decreases the incidence of obesity among men.

The empirical findings imply that policies which affect family income may influence body-weight outcomes. Most importantly, these findings suggest that it is the health of poorer women which benefits the most from incomes policies. Using the estimated coefficients from the IV model, the impact of two income policy experiments is used to simulate the effect on the heath outcome of interest to this study, obesity. The first policy experiment considers the implementation of a redistributive program which increases the income of the poorest quartile female by 10% and finances the policy by taxing the income of either the middle quartiles or the highest quartile. In this case, we find a reduction of about 2% in the overall rate of obesity, comprised mostly of a 4.8% reduction in the obesity rate of poor women. We also simulate the impact of the 1997 child-support guidelines on the body weight of custodial mothers, assuming that child support is paid by males and is received by females. The results are quite striking. The probability that a female single mother is obese falls by 12% as a result of the child-support provided to her household, while the non-custodial father's probability of being obese rises by only 2% as a result of the reduction in his household income. These results clearly demonstrate that child support policies play a key role not only in attenuating poverty amongst female-headed households but also in promoting health.

The numbers generated from our policy simulations are meant to be illustrative of the health impact of redistributive income policies. What is important here is the demonstration that public policies which are intended to reduce income inequality or poverty will indeed also have a measurable impact on health outcomes. The simulation findings therefore provide meaningful support of the view of population health experts, such as Fraser Mustard, who have long argued that an income policy is a health policy.

## 3.A Tables, Graphs, and Appendix

**Table 1 Definition of variables**

| Variable | Definition |
|---|---|
| BMI | Weight in kilograms divided by height in meters squared |
| Obese | Equal to 1 if body mass index ≥ 30 kg/m2 |
| Household income | Self-reported best estimated total household income in the past 12 months, before taxes and deductions, of all household members from all sources |
| Age | Age of the respondent |
| Agesq | Square of the respondent's age |
| Male | Equal to 1 if respondent is male |
| Unmarried | Equal to 1 if respondent is single, divorced/separated, or widowed, **reference group** |
| Married | Equal to 1 if respondent is married or living in common-law |
| Householdsize | Number of household members |
| Children | Equal to 1 if has at least one child less than 12 years old |
| CMA | Equal to 1 if respondent resides in the central metropolitan area |
| Ont | Equal to 1 if respondent resides in Ontario, **reference group** |
| Atlantic | Equal to 1 of respondent resides in Newfoundland, NB, NS, and PEI |
| Prairie | Equal to 1 if respondent resides in Alberta, Saskatchewan, and Manitoba |
| BC | Equal to 1 if respondent resides in British Columbia |
| Que | Equal to 1 if respondent resides in Quebec. |
| Primschool | Equal to 1 if the respondent has no secondary school graduation certificate, **reference group** |
| Highschool | Equal to 1 if high school diploma is the highest degree |
| College | Equal to 1 if college diploma or certificates is highest degree |
| University | Equal to 1 if respondent has a bachelor degree or above |
| White | Equal to1 if respondent claims origin as white, **reference group** |
| Asian | Equal to1 if respondent claims origin as Chinese, Japanese, Korean, Filipino, South East Asian or West Asian only |
| Black | Equal to 1 if respondent claims origin as Black only |
| Aborig | Equal to 1 if respondent is Aboriginal person of North America only |
| Latin | Equal to 1 if respondent claims origin as Latin American only |
| Other | Equal to 1 if respondent claims origin as other or all of those who have multiple racial/cultural origin |
| Canadian | Equal to 1 if respondent is born in Canada or his length of time in Canada since immigration is no less than 10 years, **reference group** |
| Imm<5 | Equal to 1 if respondent's length of time in Canada since immigration is less than 5 years |
| 5≤Imm<10 | Equal to 1 if respondent's length of time in Canada since immigration is no less than 5 years, but less than 10 years |

**Table 1 (continued)**

| Variable | Definition |
|---|---|
| Heavy drinker | Equal to 1 if respondent has five or more drinks on a single occasion no less than once a week |
| Former drinker | Equal to 1 if respondent ever drank more than 12 drinks a week but does not drink now |
| Normal drinker | Equal to 1 if respondent is neither a heavey drinker nor former drinker, **reference group** |
| Non-smoker | Equal to 1 if respondent smokes does not smoke and was not a smoker in the past two years, **reference group** |
| Smoker | Equal to 1 if respondent smokes daily or occasionally at current time |
| Former smoker | Equal to 1 if respondent was a smoker in the past two years but does not smoke now |
| Workhour | Total usual hours worked per week |
| Act restriction | Equal to 1 if respondent has any difficulty hearing, seeing, communicating, walking, climbing stairs, bending, learning or doing any similar activities. |
| Sedentary work | Equal to 1 if "usually sit" is the best to describe the respondent's level of physical activity for usual day over the past 3 months, **reference group** |
| Stand work | Equal to 1 if "stand or walk quite a lot" is the best to describe the respondent's level of physical activity for a usual day over the past 3 months |
| Light work | Equal to 1 if "lift or carry light loads" is the best way to describe the respondent's level of physical activity for usual day over the past 3 months |
| Heavy work | Equal to1 if "do heavy work or carry very heavy loads" is the best way to describe the respondent's level of physical activity for usual day over the past 3 months |
| Nutrition | Total number of daily consumption of fruits and vegetables |
| Exercise | The metabolic value of the energy expended from the frequency and duration of physical leisure activities |
| Exercise-FR | Total number of monthly leisure time physical activities which last at least 15 minutes in duration over the past 3 months. |
| FreqVeg | Equal to 1 if daily fruits and vegetables servings is no less than 5 |
| ActivExer | Equal to 1 if the calculated energy expenditure value is no less than 3 |
| Hhighschool | Equal to 1 if high school diploma is the highest level of education in the household |
| Hcollege | Equal to 1 if college diploma or certificates is the highest level of education in the household |
| Huniversity | Equal to 1 if a bachelor degree or above is the highest level of education in the household |
| Urate | Unemployment rate in each health region |
| Dwelling owned | Equal to 1 if the dwelling is owned by a household member |
| Bedroom | Number of bedrooms in the respondent's house |
| Dividend and interest | Equal to 1 if respondents report dividend and interest income |

**Table 2 Descriptive statistics for sample variables**

| Variable | Men | | Women | |
|---|---|---|---|---|
| | **Mean** | **Std. Dev.** | **Mean** | **Std. Dev.** |
| BMI | 26.49 | 66.47 | 25.17 | 74.43 |
| Obese | 0.17 | 5.65 | 0.16 | 5.12 |
| Income | 70.60 | 787.78 | 62.01 | 632.07 |
| Age | 41.71 | 171.57 | 42.08 | 159.05 |
| Married | 0.71 | 6.78 | 0.70 | 6.46 |
| Hhsize | 3.01 | 20.87 | 2.98 | 19.40 |
| Children | 0.31 | 6.94 | 0.32 | 6.58 |
| CMA | 0.66 | 6.59 | 0.67 | 6.66 |
| Ont | 0.39 | 7.33 | 0.40 | 6.91 |
| Atlantic | 0.07 | 3.88 | 0.08 | 3.77 |
| Prairie | 0.16 | 5.50 | 0.15 | 5.08 |
| BC | 0.12 | 4.93 | 0.12 | 4.64 |
| Que | 0.25 | 6.53 | 0.25 | 6.14 |
| Primschool | 0.15 | 5.41 | 0.15 | 4.95 |
| Highschool | 0.26 | 6.59 | 0.28 | 6.36 |
| College | 0.36 | 7.20 | 0.36 | 6.79 |
| University | 0.23 | 6.30 | 0.21 | 5.79 |
| White | 0.87 | 5.09 | 0.87 | 4.75 |
| Asian | 0.08 | 4.11 | 0.08 | 3.76 |
| Black | 0.01 | 1.82 | 0.02 | 1.88 |
| Aborig | 0.01 | 1.34 | 0.01 | 1.38 |
| Latin | 0.01 | 1.37 | 0.01 | 1.32 |
| Other | 0.02 | 2.09 | 0.01 | 1.69 |
| Canadian | 0.95 | 3.38 | 0.95 | 3.07 |
| Imm<5 | 0.03 | 2.38 | 0.02 | 2.04 |
| 5≤Imm<10 | 0.03 | 2.48 | 0.03 | 2.28 |

**Table 2 (continued)**

| Variable | Men | | Women | |
|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. |
| Normal drinker | 0.85 | 5.30 | 0.97 | 2.65 |
| Heavy drinker | 0.11 | 4.74 | 0.02 | 2.20 |
| Former drinker | 0.03 | 2.70 | 0.01 | 1.52 |
| Non-smoker | 0.20 | 6.04 | 0.19 | 5.58 |
| Smoker | 0.31 | 6.93 | 0.27 | 6.27 |
| Former smoker | 0.00 | 0.71 | 0.00 | 0.69 |
| Workhour | 20.71 | 369.70 | 15.46 | 288.14 |
| Act restriction | 0.21 | 6.10 | 0.22 | 5.88 |
| Sedentary work | 0.25 | 6.53 | 0.27 | 6.22 |
| Stand work | 0.39 | 7.31 | 0.48 | 7.06 |
| Light work | 0.23 | 6.32 | 0.21 | 5.80 |
| Heavy work | 0.13 | 5.08 | 0.04 | 2.74 |
| Nutrition | 4.29 | 36.56 | 5.01 | 36.48 |
| Exercise | 2.06 | 32.33 | 1.78 | 26.07 |
| Exercise-FR | 23.11 | 340.25 | 22.91 | 307.63 |
| FreqVeg | 0.30 | 6.91 | 0.44 | 7.03 |
| ActivExer | 0.25 | 6.49 | 0.20 | 5.63 |
| Hhighschool | 0.19 | 5.95 | 0.19 | 5.59 |
| Hcollege | 0.42 | 7.42 | 0.42 | 6.99 |
| Huniversity | 0.31 | 6.96 | 0.31 | 6.51 |
| Urate | 7.33 | 40.60 | 7.34 | 38.72 |
| Dwelling owned | 0.73 | 6.68 | 0.72 | 6.34 |
| Bedroom | 2.94 | 15.92 | 2.92 | 14.49 |
| Dividend& interest | 0.19 | 5.88 | 0.16 | 5.17 |
| Pooled sample size | 57,813 | | 59,336 | |

**Data source:** 2000/01 and 2003 Canadian Community Health Survey

**Table 3**
**OLS and IV regressions on body mass index, men aged 18-64, sample size=57,813**

| Variables | Conventional OLS | | IV regression | |
|---|---|---|---|---|
| | **Coef** | **t-value_rb** | **Coef** | **t-value_rb** |
| Intercept | 21.5258 | 43.38 | 24.4718 | 17.72 |
| **Household income** | | | | |
| Logincome | 0.1315 | 4.63 | -0.1652 | -1.26 |
| **Personal and household characteristics** | | | | |
| Age | 0.2039 | 10.37 | 0.2086 | 10.68 |
| Agesq | -0.0021 | -9.09 | -0.0022 | -9.46 |
| Hhsize | 0.0464 | 1.35 | 0.0850 | 2.06 |
| Children | -0.1969 | -2.24 | -0.2676 | -2.84 |
| Married | 0.4951 | 6.54 | 0.5889 | 7.09 |
| Highschool | -0.2378 | -2.60 | -0.1563 | -1.57 |
| College | -0.2605 | -3.05 | -0.1603 | -1.70 |
| University | -1.1021 | -10.32 | -0.9203 | -6.77 |
| **Geography** | | | | |
| CMA | -0.2214 | -3.89 | -0.1821 | -3.04 |
| Atlantic | 0.2217 | 2.42 | 0.1372 | 1.40 |
| Prairie | 0.1503 | 1.82 | 0.1314 | 1.59 |
| BC | -0.5640 | -7.08 | -0.5975 | -7.43 |
| Que | -0.6866 | -7.84 | -0.7479 | -8.56 |
| **Ethnic characteristics** | | | | |
| Asian | -2.2179 | -18.66 | -2.3218 | -18.33 |
| Black | -0.9476 | -4.64 | -1.0196 | -4.91 |
| Aborig | 1.3208 | 3.93 | 1.2148 | 3.52 |
| Latin | 0.3128 | 1.04 | 0.1257 | 0.41 |
| Other | 0.0493 | 0.11 | -0.0465 | -0.10 |
| Imm<5 | -0.6758 | -3.26 | -0.9052 | -3.86 |
| 5≤Imm<10 | -0.3694 | -1.80 | -0.4626 | -2.21 |
| **Addictive life habits** | | | | |
| Heavy drinker | 0.1901 | 2.26 | 0.2142 | 2.51 |
| Former drinker | 0.4091 | 3.02 | 0.3761 | 2.77 |
| Smoker | -1.1046 | -17.56 | -1.1437 | -17.49 |
| Former smoker | -0.0692 | -0.17 | -0.1129 | -0.27 |
| **Physical activities in a usual day** | | | | |
| Act restriction | 0.7645 | 9.39 | 0.7238 | 9.02 |
| Workhour | -0.0016 | -1.42 | -0.0010 | -0.86 |
| Standwork | -0.4113 | -5.56 | -0.4307 | -5.79 |
| Lightwork | -0.5352 | -5.83 | -0.5468 | -5.91 |
| Heavywork | -0.4403 | -4.94 | -0.4518 | -5.04 |
| R-square | 0.0796 | | 0.0789 | |

Note: 1. The reference group for the regression is an unmarried individual, with no children, with no high school diploma, living in a non-CMA in Ontario, white, born in Canada or immigrated more than 10 years ago, a normal drinker and non-smoker, without activity restrictions and usually sitting in work.
2. The critical values for the estimated coefficient to be significant at the 10%, 5%, and 1% levels are respectively 1.645, 1.960, and 2.576.

**Table 4**

**OLS and IV regressions on body mass index, women aged 18-64, sample size=59,336**

| Variables | Conventional OLS | | IV regression | |
|---|---|---|---|---|
| | Coef | t-value_rb | Coef | t-value_rb |
| Intercept | 24.9765 | 49.35 | 39.1334 | 24.68 |
| **Household income** | | | | |
| Logincome | -0.2173 | -6.57 | -1.7227 | -10.18 |
| **Personal and household characteristics** | | | | |
| Age | 0.1532 | 7.38 | 0.1958 | 9.03 |
| Agesq | -0.0012 | -4.79 | -0.0018 | -6.68 |
| Hhsize | 0.1304 | 2.92 | 0.3292 | 6.00 |
| Children | -0.2181 | -2.01 | -0.5475 | -4.49 |
| Married | -0.0396 | -0.49 | 0.6685 | 6.16 |
| Highschool | -0.6829 | -6.01 | -0.2354 | -1.85 |
| College | -0.8361 | -7.58 | -0.2364 | -1.83 |
| University | -1.9514 | -16.27 | -0.9399 | -5.76 |
| **Geography** | | | | |
| CMA | -0.4777 | -7.40 | -0.2381 | -3.28 |
| Atlantic | 0.7719 | 7.32 | 0.3610 | 3.03 |
| Prairie | 0.2103 | 2.42 | 0.1061 | 1.19 |
| BC | -0.5807 | -6.65 | -0.7093 | -7.90 |
| Que | -0.7639 | -8.65 | -1.0706 | -10.95 |
| **Ethnic characteristics** | | | | |
| Asian | -2.1665 | -15.62 | -2.6043 | -16.96 |
| Black | 0.5599 | 1.89 | 0.0847 | 0.28 |
| Aborig | 1.6655 | 6.25 | 1.2369 | 4.54 |
| Latin | 0.4174 | 0.91 | 0.1263 | 0.28 |
| Other | -0.1396 | -0.47 | -0.7533 | -2.49 |
| Imm<5 | -0.5555 | -2.30 | -1.7077 | -6.23 |
| 5≤Imm<10 | -0.8225 | -4.14 | -1.4768 | -7.00 |
| **Addictive life habits** | | | | |
| Heavy drinker | -0.5745 | -3.52 | -0.4647 | -2.84 |
| Former drinker | 0.2407 | 0.76 | -0.1181 | -0.37 |
| Smoker | -1.0152 | -13.90 | -1.1732 | -15.53 |
| Former smoker | -1.2306 | -2.47 | -1.2639 | -2.54 |
| **Physical activities in a usual day** | | | | |
| Act restriction | 1.6871 | 20.12 | 1.4597 | 16.31 |
| Workhour | -0.0019 | -1.20 | 0.0017 | 1.07 |
| Standwork | -0.5736 | -7.32 | -0.7577 | -9.56 |
| Lightwork | -0.6441 | -7.28 | -0.8356 | -9.12 |
| Heavywork | -0.3887 | -2.43 | -0.5097 | -3.17 |
| R-square | 0.1082 | | 0.1106 | |

Note: The reference group is same as that for table 3. The critical values for the estimated coefficients to be significant at the 10%, 5%, and 1% level are respectively 1.645, 1.960, and 2.576

**Table 5 Probit regression on obesity, men aged 18-64, sample size=57,813**

| Variables | Conventional regression | | IV regression | |
|---|---|---|---|---|
| | Coef | Wald Statistic | Coef | Wald Statistic |
| Intercept | -1.4819 | 177.79 | -0.7829 | 6.63 |
| **Household income** | | | | |
| Logincome | 0.0024 | 0.11 | -0.0681 | 5.37 |
| **Personal and household characteristics** | | | | |
| Age | 0.0370 | 77.36 | 0.0382 | 81.36 |
| Agesq | -0.0004 | 61.30 | -0.0004 | 65.53 |
| Hhsize | 0.0279 | 23.15 | 0.0367 | 28.90 |
| Children | -0.0975 | 30.20 | -0.1141 | 36.13 |
| Married | 0.0756 | 19.36 | 0.0985 | 25.45 |
| Highschool | -0.0937 | 21.63 | -0.0744 | 11.84 |
| College | -0.1227 | 40.90 | -0.0991 | 21.33 |
| University | -0.3917 | 288.38 | -0.3483 | 144.83 |
| **Geography** | | | | |
| CMA | -0.0786 | 31.79 | -0.0692 | 22.91 |
| Atlantic | 0.0479 | 3.72 | 0.0276 | 1.12 |
| Prairie | 0.0210 | 1.30 | 0.0164 | 0.79 |
| BC | -0.1716 | 63.11 | -0.1800 | 67.75 |
| Que | -0.1980 | 139.31 | -0.2126 | 142.91 |
| **Ethnic characteristics** | | | | |
| Asian | -0.6012 | 325.54 | -0.6258 | 323.11 |
| Black | -0.3689 | 36.34 | -0.3856 | 39.19 |
| Aborig | 0.2996 | 22.40 | 0.2749 | 18.39 |
| Latin | 0.1046 | 2.32 | 0.0598 | 0.71 |
| Other | -0.0316 | 0.45 | -0.0543 | 1.27 |
| Imm<5 | -0.1171 | 4.85 | -0.1706 | 8.82 |
| 5≤Imm<10 | -0.0860 | 3.14 | -0.1089 | 4.86 |
| **Addictive life habits** | | | | |
| Heavy drinker | 0.0257 | 1.60 | 0.0314 | 2.35 |
| Former drinker | 0.1658 | 25.80 | 0.1578 | 23.16 |
| Smoker | -0.1997 | 185.39 | -0.2090 | 190.06 |
| Former smoker | -0.0149 | 0.01 | -0.0269 | 0.04 |
| **Physical activities in a usual day** | | | | |
| Act restriction | 0.2088 | 189.33 | 0.1990 | 161.23 |
| Workhour | 0.0001 | 0.10 | 0.0002 | 0.74 |
| Standwork | -0.1566 | 92.99 | -0.1610 | 97.11 |
| Lightwork | -0.1847 | 98.13 | -0.1873 | 100.52 |
| Heavywork | -0.1629 | 54.71 | -0.1654 | 56.30 |
| Log likelihood | 50652.7 | | 50647.4 | |

Note: The reference group is same as that for table 3. The critical values for the estimated coefficients to be significant at the 10%, 5%, and 1% levels are respectively 2.706, 3.841, and 6.635.

**Table 6 Probit regression on obesity, women aged 18-64, sample size=59,336**

| Variables | Conventional regression | | IV regression | |
|---|---|---|---|---|
| | Coef | Wald Statistic | Coef | Wald Statistic |
| Intercept | -0.7665 | 49.91 | 2.1528 | 50.89 |
| **Household income** | | | | |
| Logincome | -0.0452 | 44.58 | -0.3563 | 133.51 |
| **Personal and household Characteristics** | | | | |
| Age | 0.0256 | 35.63 | 0.0346 | 62.35 |
| Agesq | -0.0002 | 20.81 | -0.0004 | 45.01 |
| Hhsize | 0.0252 | 16.06 | 0.0656 | 78.01 |
| Children | -0.0334 | 3.51 | -0.1021 | 28.72 |
| Married | -0.0887 | 30.34 | 0.0601 | 7.70 |
| Highschool | -0.1514 | 55.88 | -0.0589 | 7.06 |
| College | -0.1848 | 88.43 | -0.0609 | 6.94 |
| University | -0.4962 | 423.17 | -0.2855 | 81.56 |
| **Geography** | | | | |
| CMA | -0.1082 | 57.68 | -0.0588 | 15.32 |
| Atlantic | 0.1682 | 48.38 | 0.0827 | 10.47 |
| Prairie | 0.0397 | 4.27 | 0.0171 | 0.78 |
| BC | -0.1483 | 44.48 | -0.1784 | 63.16 |
| Que | -0.1291 | 56.88 | -0.1949 | 114.04 |
| **Ethnic Characteristics** | | | | |
| Asian | -0.6192 | 292.13 | -0.7121 | 363.36 |
| Black | 0.0597 | 1.59 | -0.0363 | 0.57 |
| Aborig | 0.3120 | 29.23 | 0.2249 | 14.84 |
| Latin | -0.0023 | 0.00 | -0.0644 | 0.83 |
| Other | -0.0555 | 0.95 | -0.1840 | 9.98 |
| Imm<5 | -0.1715 | 7.77 | -0.4086 | 38.71 |
| 5≤Imm<10 | -0.3277 | 32.36 | -0.4701 | 62.72 |
| **Addictive life habits** | | | | |
| Heavy drinker | -0.2585 | 30.21 | -0.2348 | 24.85 |
| Former drinker | 0.0775 | 1.98 | 0.0028 | 0.00 |
| Smoker | -0.2163 | 194.96 | -0.2497 | 248.08 |
| Former smoker | -0.2962 | 3.59 | -0.2975 | 3.63 |
| **Physical activities in a usual day** | | | | |
| Act restriction | 0.4157 | 800.26 | 0.3696 | 578.87 |
| Workhour | -0.0007 | 5.14 | 0.0000 | 0.00 |
| Standwork | -0.1473 | 88.56 | -0.1838 | 130.64 |
| Lightwork | -0.1768 | 86.43 | -0.2151 | 122.71 |
| Heavywork | -0.0831 | 5.87 | -0.1057 | 9.44 |
| Log likelihood | 47539.4 | | 47976.8 | |

Note: The reference group is same as that for table 3. The critical values for the estimated coefficients to be significant at the 10%, 5%, and 1% levels are respectively 2.706, 3.841, and 6.635.

**Table 3-1 OLS and IV regressions on body mass index including two pathways, men aged 18-64, sample size=57,813**

| Variables | Conventional OLS | | IV regression | |
|---|---|---|---|---|
| | Coef | t-value_rb | Coef | t-value_rb |
| Intercept | 21.7482 | 42.39 | 24.1891 | 17.67 |
| Logincome | 0.1418 | 5.05 | -0.1078 | -0.82 |
| Nutrition | -0.0114 | -0.82 | -0.0099 | -0.71 |
| Exercise | -0.0632 | -4.17 | -0.0563 | -3.77 |
| Age | 0.1968 | 9.74 | 0.2015 | 10.01 |
| Agesq | -0.0020 | -8.59 | -0.0021 | -8.90 |
| Hhsize | 0.0484 | 1.41 | 0.0805 | 1.97 |
| Children | -0.2042 | -2.32 | -0.2626 | -2.78 |
| Married | 0.4811 | 6.29 | 0.5611 | 6.62 |
| Highschool | -0.2228 | -2.43 | -0.1563 | -1.57 |
| College | -0.2366 | -2.79 | -0.1554 | -1.66 |
| University | -1.0502 | -9.80 | -0.9038 | -6.72 |
| CMA | -0.2210 | -3.89 | -0.1881 | -3.13 |
| Atlantic | 0.2050 | 2.24 | 0.1362 | 1.39 |
| Prairie | 0.1516 | 1.83 | 0.1358 | 1.64 |
| BC | -0.5349 | -6.58 | -0.5662 | -6.87 |
| Que | -0.7017 | -8.15 | -0.7514 | -8.68 |
| Asian | -2.2589 | -18.95 | -2.3413 | -18.47 |
| Black | -0.9503 | -4.63 | -1.0103 | -4.84 |
| Aborig | 1.3541 | 4.06 | 1.2616 | 3.69 |
| Latin | 0.3051 | 1.01 | 0.1492 | 0.48 |
| Other | 0.0307 | 0.07 | -0.0476 | -0.11 |
| Imm<5 | -0.6869 | -3.29 | -0.8779 | -3.72 |
| 5≤Imm<10 | -0.3971 | -1.92 | -0.4722 | -2.24 |
| Heavy drinker | 0.1924 | 2.28 | 0.2125 | 2.48 |
| Former drinker | 0.4232 | 3.14 | 0.3940 | 2.91 |
| Smoker | -1.1325 | -17.97 | -1.1620 | -17.81 |
| Former smoker | -0.0772 | -0.18 | -0.1130 | -0.27 |
| Workhour | -0.0019 | -1.78 | -0.0014 | -1.26 |
| Act restriction | 0.7487 | 9.27 | 0.7163 | 8.97 |
| Standwork | -0.3887 | -5.24 | -0.4075 | -5.45 |
| Lightwork | -0.5108 | -5.65 | -0.5232 | -5.74 |
| Heavywork | -0.4191 | -4.70 | -0.4312 | -4.80 |
| R-square | 0.0806 | | 0.0798 | |

Note: The reference group is same as that for table 3. The critical values for the estimated coefficients to be significant at the 10%, 5%, and 1% levels are respectively 1.645, 1.960, and 2.576.

**Table 4-1 OLS and IV regressions on body mass index including two pathways, women aged 18-64, sample size=59,336**

| Variables | Conventional OLS | | IV regression | |
|---|---|---|---|---|
| | Coef | t-value_rb | Coef | t-value_rb |
| Intercept | 25.3845 | 50.12 | 38.1292 | 23.67 |
| Logincome | -0.1837 | -5.65 | -1.5527 | -8.89 |
| Nutrition | -0.0262 | -1.94 | -0.0155 | -1.14 |
| Exercise | -0.2747 | -16.13 | -0.2383 | -13.03 |
| Age | 0.1471 | 7.07 | 0.1868 | 8.54 |
| Agesq | -0.0012 | -4.63 | -0.0017 | -6.32 |
| Hhsize | 0.1192 | 2.64 | 0.3007 | 5.35 |
| Children | -0.2467 | -2.28 | -0.5421 | -4.41 |
| Married | -0.0676 | -0.83 | 0.5766 | 5.23 |
| Highschool | -0.6101 | -5.37 | -0.2165 | -1.71 |
| College | -0.7125 | -6.40 | -0.1903 | -1.48 |
| University | -1.7431 | -14.26 | -0.8618 | -5.31 |
| CMA | -0.4974 | -7.73 | -0.2780 | -3.80 |
| Atlantic | 0.6946 | 6.65 | 0.3359 | 2.85 |
| Prairie | 0.2486 | 2.87 | 0.1509 | 1.69 |
| BC | -0.4424 | -5.04 | -0.5776 | -6.33 |
| Que | -0.8384 | -9.49 | -1.1088 | -11.36 |
| Asian | -2.3281 | -16.85 | -2.7012 | -17.72 |
| Black | 0.4510 | 1.51 | 0.0347 | 0.11 |
| Aborig | 1.6686 | 6.21 | 1.2802 | 4.66 |
| Latin | 0.3064 | 0.67 | 0.0571 | 0.12 |
| Other | -0.2146 | -0.73 | -0.7623 | -2.52 |
| Imm<5 | -0.6591 | -2.72 | -1.6885 | -6.12 |
| 5≤Imm<10 | -0.8765 | -4.38 | -1.4611 | -6.86 |
| Heavy drinker | -0.5258 | -3.23 | -0.4326 | -2.65 |
| Former drinker | 0.2206 | 0.71 | -0.0989 | -0.31 |
| Smoker | -1.1117 | -15.25 | -1.2371 | -16.51 |
| Former smoker | -1.2103 | -2.44 | -1.2448 | -2.50 |
| Workhour | -0.0037 | -2.40 | -0.0002 | -0.16 |
| Act restriction | 1.6176 | 19.49 | 1.4213 | 16.09 |
| Standwork | -0.4809 | -6.18 | -0.6622 | -8.36 |
| Lightwork | -0.4809 | -5.42 | -0.6798 | -7.28 |
| Heavywork | -0.2017 | -1.28 | -0.3399 | -2.12 |
| R-square | 0.1082 | | 0.1121 | |

Note: The reference group is same as that for table 3. The critical values for the estimated coefficients to be significant at the 10%, 5%, and 1% levels are respectively 1.645, 1.960, and 2.576.

**Table 5-1 Probit regression on obesity including two pathways, men aged 18-64, sample size=57,813**

| Variables | Conventional regression | | IV regression | |
|---|---|---|---|---|
| | Coef | Wald Statistic | Coef | Wald Statistic |
| Intercept | -1.3662 | 147.21 | -0.9958 | 10.50 |
| Logincome | 0.0084 | 1.38 | -0.0295 | 0.96 |
| Nutrition | -0.0010 | 0.14 | -0.0008 | 0.09 |
| Exercise | -0.0450 | 178.85 | -0.0440 | 160.87 |
| Age | 0.0333 | 61.87 | 0.0340 | 63.51 |
| Agesq | -0.0004 | 50.57 | -0.0004 | 52.21 |
| Hhsize | 0.0285 | 24.13 | 0.0332 | 23.36 |
| Children | -0.1025 | 33.22 | -0.1113 | 34.16 |
| Married | 0.0681 | 15.65 | 0.0806 | 16.71 |
| Highschool | -0.0848 | 17.66 | -0.0748 | 11.95 |
| College | -0.1081 | 31.46 | -0.0958 | 19.94 |
| University | -0.3619 | 242.01 | -0.3396 | 138.06 |
| CMA | -0.0788 | 31.80 | -0.0738 | 25.88 |
| Atlantic | 0.0393 | 2.49 | 0.0287 | 1.20 |
| Prairie | 0.0238 | 1.66 | 0.0213 | 1.32 |
| BC | -0.1532 | 49.89 | -0.1580 | 51.51 |
| Que | -0.2093 | 154.73 | -0.2169 | 148.40 |
| Asian | -0.6289 | 353.54 | -0.6412 | 338.95 |
| Black | -0.3669 | 36.05 | -0.3759 | 37.34 |
| Aborig | 0.3193 | 25.22 | 0.3057 | 22.49 |
| Latin | 0.1005 | 2.14 | 0.0761 | 1.14 |
| Other | -0.0480 | 1.02 | -0.0600 | 1.54 |
| Imm<5 | -0.1255 | 5.56 | -0.1532 | 7.08 |
| 5≤Imm<10 | -0.1059 | 4.75 | -0.1176 | 5.65 |
| Heavy drinker | 0.0289 | 2.02 | 0.0320 | 2.43 |
| Former drinker | 0.1739 | 28.22 | 0.1694 | 26.50 |
| Smoker | -0.2152 | 212.33 | -0.2197 | 209.48 |
| Former smoker | -0.0202 | 0.02 | -0.0278 | 0.04 |
| Workhour | -0.0002 | 0.43 | -0.0001 | 0.11 |
| Act restriction | 0.1988 | 170.48 | 0.1937 | 152.58 |
| Standwork | -0.1425 | 76.50 | -0.1452 | 78.01 |
| Lightwork | -0.1703 | 82.82 | -0.1720 | 84.07 |
| Heavywork | -0.1519 | 47.30 | -0.1536 | 48.17 |
| Log likelihood | 50452.8 | | 50453.2 | |

Note: The reference group is same as that for table 3. The critical values for the estimated coefficients to be significant at the 10%, 5%, and 1% levels are respectively 2.706, 3.841, and 6.635.

**Table 6-1 Probit regression on obesity including two pathways, women aged 18-64, sample size=59,336**

| Variables | Conventional regression | | IV regression | |
|---|---|---|---|---|
| | Coef | Wald Statistic | Coef | Wald Statistic |
| Intercept | -0.6288 | 32.58 | 1.8856 | 37.92 |
| Logincome | -0.0358 | 26.69 | -0.3065 | 94.08 |
| Nutrition | -0.0103 | 14.52 | -0.0080 | 8.69 |
| Exercise | -0.0896 | 409.48 | -0.0824 | 335.29 |
| Age | 0.0239 | 30.77 | 0.0320 | 52.38 |
| Agesq | -0.0002 | 18.83 | -0.0003 | 38.55 |
| Hhsize | 0.0217 | 11.80 | 0.0570 | 57.46 |
| Children | -0.0396 | 4.88 | -0.0985 | 26.45 |
| Married | -0.0962 | 35.21 | 0.0333 | 2.30 |
| Highschool | -0.1302 | 40.91 | -0.0523 | 5.54 |
| College | -0.1493 | 56.65 | -0.0461 | 3.97 |
| University | -0.4381 | 320.96 | -0.2621 | 68.62 |
| CMA | -0.1147 | 63.99 | -0.0715 | 22.21 |
| Atlantic | 0.1451 | 35.48 | 0.0739 | 8.28 |
| Prairie | 0.0512 | 6.98 | 0.0312 | 2.55 |
| BC | -0.1104 | 24.15 | -0.1396 | 37.78 |
| Que | -0.1479 | 73.40 | -0.2035 | 122.67 |
| Asian | -0.6669 | 335.29 | -0.7428 | 393.22 |
| Black | 0.0256 | 0.29 | -0.0547 | 1.27 |
| Aborig | 0.3189 | 30.22 | 0.2432 | 17.17 |
| Latin | -0.0367 | 0.27 | -0.0881 | 1.54 |
| Other | -0.0837 | 2.14 | -0.1942 | 10.98 |
| Imm<5 | -0.2042 | 10.91 | -0.4082 | 38.18 |
| 5≤Imm<10 | -0.3453 | 35.65 | -0.4675 | 61.57 |
| Heavy drinker | -0.2527 | 28.40 | -0.2337 | 24.25 |
| Former drinker | 0.0736 | 1.77 | 0.0100 | 0.03 |
| Smoker | -0.2500 | 253.32 | -0.2754 | 296.32 |
| Former smoker | -0.2900 | 3.40 | -0.2941 | 3.51 |
| Workhour | -0.0013 | 15.79 | -0.0006 | 3.12 |
| Act restriction | 0.3979 | 723.50 | 0.3599 | 544.32 |
| Standwork | -0.1167 | 54.64 | -0.1514 | 86.15 |
| Lightwork | -0.1274 | 43.78 | -0.1656 | 70.11 |
| Heavywork | -0.0311 | 0.81 | -0.0564 | 2.63 |
| Log likelihood | 47539.4 | | 47468.8 | |

Note: The reference group is same as that for table 3. The critical values for the estimated coefficients to be significant at the 10%, 5%, and 1% levels are respectively 2.706, 3.841, and 6.635.

**Table 7 Percentage change in the risk of obesity for the reference individual**

| Variable | Men | | Women | |
|---|---|---|---|---|
| | Conventional | IV estimates | Conventional | IV estimates |
| **Age** | | | | |
| 20 | -33.0% | -33.0% | -33.5% | -37.3% |
| 30 | -13.5% | -13.2% | -15.6% | -16.2% |
| 50 | 1.2% | 0.1% | 5.4% | 2.9% |
| 60 | -6.4% | -8.4% | 5.7% | -3.2% |
| **Household** | | | | |
| Unmarried | -9.6% | -12.5% | 14.3% | -8.6% |
| Without children | 13.2% | 15.6% | 4.9% | 15.7% |
| **Education** | | | | |
| Primschool | 16.8% | 13.5% | 29.8% | 8.6% |
| Highschool | 3.8% | 3.3% | 5.8% | 1.0% |
| University | -31.7% | -29.6% | -38.6% | -28.0% |
| **Geography** | | | | |
| Not in CMA | 10.6% | 9.3% | 48.4% | 16.7% |
| Atlantic | 6.4% | 3.7% | 26.1% | 11.5% |
| Prairie | 2.8% | 2.2% | 5.2% | 1.6% |
| BC | -21.1% | -22.1% | -21.0% | -24.4% |
| Que | -24.0% | -25.7% | -18.6% | -26.7% |
| **Ethnicity/immigrant** | | | | |
| Asia | -60.6% | -62.4% | -66.4% | -71.5% |
| Black | -41.5% | -43.2% | 8.0% | -6.4% |
| Aboriginal | 43.2% | 39.5% | 52.9% | 35.8% |
| Imm<5 | -14.7% | -21.0% | -18.9% | -46.3% |
| 5≤Imm<10 | -10.9% | -13.7% | -42.4% | -54.8% |
| **Addictive life habit** | | | | |
| Heavy drinker | 3.4% | 4.2% | -33.6% | -30.2% |
| Smoker | -24.2% | -25.3% | -28.6% | -32.0% |
| **Usual daily activity** | | | | |
| Standwork | -19.3% | -19.9% | -21.1% | -25.3% |
| Lightwork | -22.5% | -22.9% | -24.5% | -28.8% |
| Heavywork | -20.1% | -20.4% | -12.8% | -15.6% |
| Sample size | 57,813 | | 59,336 | |

Note: The **reference individual** is described in the text of the paper. The probability of being obese for the reference man (woman) is around 21.6% (17.5%).

**Table 8 Regression results of income effect on BMI and risk of obesity**

| | BMI | | Obesity | |
|---|---|---|---|---|
| | **Conventional** | **IV estimates** | **Conventional** | **IV estimates** |
| **Men** | 0.132 *** (ε = 0.005) | -0.165 (--) | 0.002 (--) | -0.0681 ** ( %Δ= 0.0527) |
| **Women** | -0.217 *** (ε = -0.011) | -1.7227 *** (ε = -0.069) | -0.0452 *** (%Δ= 0.0362) | -0.3563 *** (%Δ =0.2757) |
| **Sample size** | Men = 57, 813 | | Women = 59,336 | |

Note : 1. Both the elasticity and changes in the relative risk of obesity are calculated at the sample mean.

2. Changes in the relative risk of obesity correspond to an increase of a half unit of log income above the mean (men from $70,600 to $116,400 and women from $62,007 to $102,232).

**Table 9 Percentage change in risk of being obese from changes in income**

| | Low | | Middle | | High | |
|---|---|---|---|---|---|---|
| | **Conventional** | **IV** | **Conventional** | **IV** | **Conventional** | **IV** |
| Starting income | 23,503 | | 59,874 | | 129,583 | |
| **Men** | | | | | | |
| increase by 2,350 | - | -0.84% | - | -0.35% | - | -0.17% |
| increase by 4,700 | - | -1.60% | - | -0.69% | - | -0.33% |
| increase by 7,050 | - | -2.29% | - | -1.02% | - | -0.50% |
| Sample Size | 13,541 | | 28,956 | | 15,316 | |
| **Women** | | | | | | |
| increase by 2,350 | -0.63% | -4.05% | -0.26% | 2.01% | -0.12% | -1.09% |
| increase by 4,700 | -1.21% | -7.69% | -0.51% | -3.92% | -0.25% | -2.15% |
| increase by 7,050 | -1.75% | -10.96% | -0.75% | -5.74% | -0.36% | -3.19% |
| Sample Size | 19,552 | | 28,533 | | 11,251 | |

Note: 1. The starting income is the weighted mean of household income in each income group.
2. \$2,350, \$4,700, and \$7,050 are respectively 10%, 20%, and 30% of the mean of the household income in the lowest income group.

**Table 10 Regression result of income effect on BMI and risk of obesity including two pathways**

| Variable | BMI | | Obesity | |
|---|---|---|---|---|
| | Conventional | IV estimates | Conventional | IV estimates |
| **Men** | 57, 813 | | | |
| Nutrition | -0.011 | -0.01 | -0.001 | -0.001 |
| Exercise | -0.063 *** | -0.056 *** | -0.045 *** | -0.044 *** |
| Income | 0.142 *** (ε =0.005 ) | -0.108 (--) | 0.008 (--) | -0.0295 (--) |
| **Women** | 59,336 | | | |
| Nutrition | -0.026 *** | -0.015 | -0.01 *** | -0.008 ** |
| Exercise | -0.275 *** | -0.238 *** | -0.09 *** | -0.082 *** |
| Income | -0.184 *** (ε = -0.007) | -1.552 *** (ε = -0.058) | -0.0360 *** (%Δ= 0.971) | -0.3065 *** (%Δ =0.746) |

Note : 1. Both the elasticity and the relative risk change are calculated at the sample mean.
2. The relative risk change is correspondent to an increase of half unit log income above the mean (men from $70,600 to $116,400 and women from $62,007 to $102,232).

**Table 11 OLS regression on daily consumption on fruits and vegetables**

| Variables | Men | | Women | |
|---|---|---|---|---|
| | Coef | t-statistic | Coef | t-statistic |
| Intercept | 4.5621 | 26.85 | 4.2116 | 24.45 |
| Logincome | 0.0745 | 6.92 | 0.0829 | 7.27 |
| Age | -0.0778 | -11.91 | -0.0571 | -8.44 |
| Agesq | 0.0010 | 12.83 | 0.0009 | 11.02 |
| Hhsize | 0.0426 | 4.69 | 0.0411 | 4.16 |
| Children | 0.0496 | 1.77 | 0.1337 | 4.79 |
| Married | 0.0344 | 1.29 | 0.1777 | 6.88 |
| Highschool | 0.1839 | 5.59 | 0.2863 | 8.30 |
| College | 0.3613 | 11.51 | 0.6495 | 19.35 |
| University | 0.6803 | 19.25 | 1.0026 | 26.35 |
| CMA | 0.0345 | 1.53 | 0.0005 | 0.02 |
| Atlantic | -0.4062 | -9.75 | -0.4569 | -10.87 |
| Prairie | -0.3777 | -12.66 | -0.2337 | -7.44 |
| BC | 0.1034 | 3.15 | 0.0715 | 2.10 |
| Que | 0.1154 | 4.45 | 0.3167 | 11.77 |
| Asian | -0.3111 | -7.52 | -0.3505 | -7.93 |
| Black | 0.2060 | 2.48 | -0.0108 | -0.14 |
| Aborig | 0.0458 | 0.41 | -0.0576 | -0.54 |
| Latin | 0.1588 | 1.44 | 0.0382 | 0.34 |
| Other | 0.2302 | 3.16 | 0.2217 | 2.53 |
| Imm<5 | 0.3435 | 5.09 | -0.1187 | -1.56 |
| 5≤Imm<10 | 0.2020 | 3.14 | -0.1233 | -1.80 |
| Heavy drinker | -0.3138 | -9.73 | -0.0020 | -0.03 |
| Smoker | -0.4498 | -19.87 | -0.6711 | -27.38 |
| R-square | 0.0376 | | 0.0536 | |
| Sample size | 57,813 | | 59,336 | |

Note: The reference group is same as that for table 3. The critical value for the coefficients to be significant at the 10%, 5%, and 1% level are respectively 1.645, 1.960, and 2.576.

**Table 12 OLS regression on monthly leisure time participation in physical activities**

| Variables | Men | | Women | |
|---|---|---|---|---|
| | Coef | t-statistic | Coef | t-statistic |
| Intercept | 25.8808 | 16.32 | 12.1838 | 8.32 |
| Logincome | 1.2690 | 12.76 | 1.2285 | 12.83 |
| Age | -0.7000 | -11.59 | -0.0550 | -0.97 |
| Agesq | 0.0068 | 9.51 | 0.0003 | -0.50 |
| Hhsize | -0.0202 | -0.24 | -0.5738 | -6.93 |
| Children | -1.4170 | -5.50 | -1.0464 | -4.48 |
| Married | -1.4004 | -5.68 | -0.5242 | -2.43 |
| Highschool | 2.1009 | 6.93 | 3.2310 | 11.20 |
| College | 3.6548 | 12.63 | 4.8031 | 17.12 |
| University | 6.6252 | 19.99 | 7.3212 | 22.98 |
| CMA | -0.0800 | -0.38 | -0.9841 | -5.01 |
| Atlantic | -2.2997 | -6.00 | -2.9733 | -8.47 |
| Prairie | 0.2950 | 1.07 | 1.3420 | 5.12 |
| BC | 3.5400 | 11.71 | 4.2640 | 14.98 |
| Que | -3.7375 | -15.58 | -4.1339 | -18.31 |
| Asian | -5.8760 | -15.39 | -6.6834 | -18.08 |
| Black | -1.9053 | -2.49 | -5.7936 | -8.78 |
| Aborig | 4.8555 | 4.68 | 0.9998 | 1.13 |
| Latin | -1.7757 | -1.74 | -7.0294 | -7.51 |
| Other | -3.9316 | -5.87 | -3.2336 | -4.41 |
| Imm<5 | -3.5443 | -5.70 | -4.1603 | -6.54 |
| 5≤Imm<10 | -5.5347 | -9.35 | -1.8175 | -3.18 |
| Heavy drinker | 0.4096 | 1.38 | 1.4064 | 2.51 |
| Smoker | -3.7999 | -18.17 | -3.3221 | -16.20 |
| Workhour | -0.0759 | -20.12 | -0.0920 | -21.30 |
| Act restriction | -1.7744 | -7.62 | -2.4400 | -11.40 |
| Standwork | 3.4680 | 14.60 | 3.8090 | 18.01 |
| Lightwork | 3.5609 | 13.03 | 6.7155 | 26.17 |
| Heavywork | 2.6220 | 8.07 | 7.1778 | 15.25 |
| R-square | 0.0582 | | 0.0732 | |
| Sample size | 57,813 | | 59,336 | |

Note: The reference group is same as that for table 3. The critical values for the coefficients to be significant at the 10%, 5%, and 1% levels are respectively 1.645, 1.960, and 2.576.

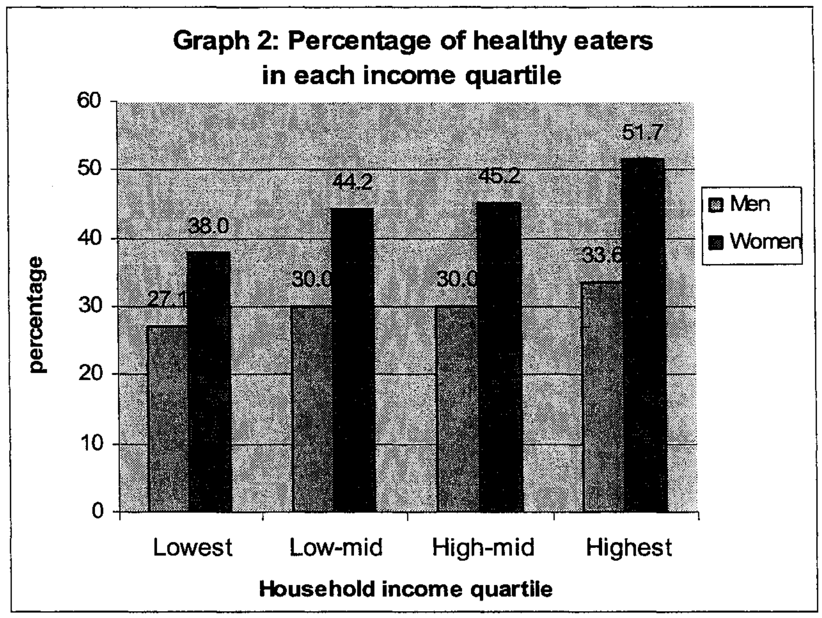
**Table 13 Simulation results of Policy I: Welfare policy**

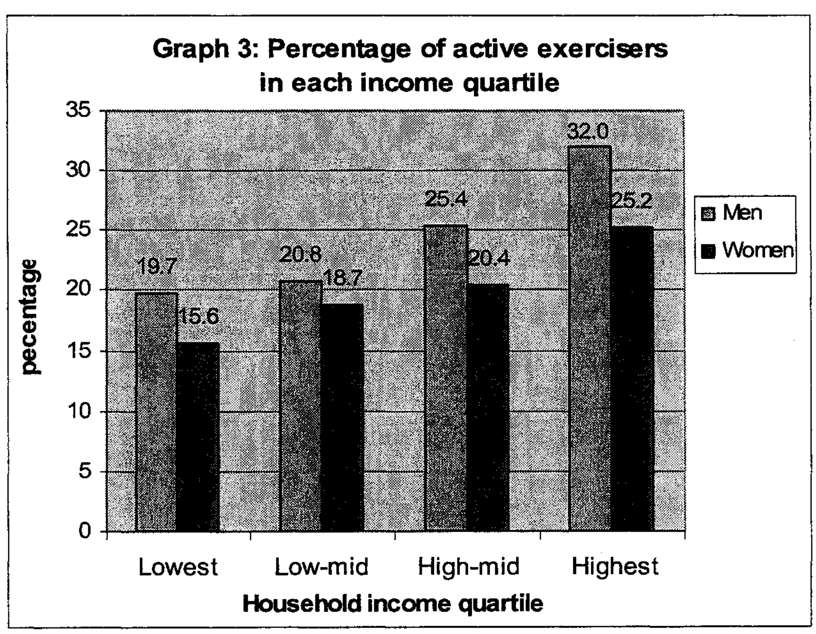
| Men | | | Women | | |
|---|---|---|---|---|---|
| **Low** | **Middle** | **High** | **Low** | **Middle** | **High** |
| **BEFORE POLICY** | | | | | |
| **Population distribution** | | | | | |
| 13,541 | 28,956 | 15,316 | 19,552 | 28,533 | 11,251 |
| **Probability of being obese at the mean** | | | | | |
| 17.19% | 15.61% | 14.39% | 20.02% | 11.81% | 7.11% |
| **Total number of obese people** | | | | | |
| | 9,052 | | | 8,086 | |
| **AFTER POLICY** | | | | | |
| **Change in Prob(obs), absolute value** | | | | | |
| / | 0.02% | 0.02% | -0.96% | 0.10% | 0.07% |
| **Change in Prob(obs), relative value** | | | | | |
| / | 0.14% | 0.15% | -4.81% | 0.83% | 0.96% |
| **Total effect on obesity: change in number and percentage** | | | | | |
| / | 6 | 3 | -188 | 28 | 8 |
| / | 0.07% | 0.03% | / | -1.98% | -2.24% |
| **Total number of obese people** | | | | | |
| | 9,058 | 9,055 | | 8,101 | 8,040 |

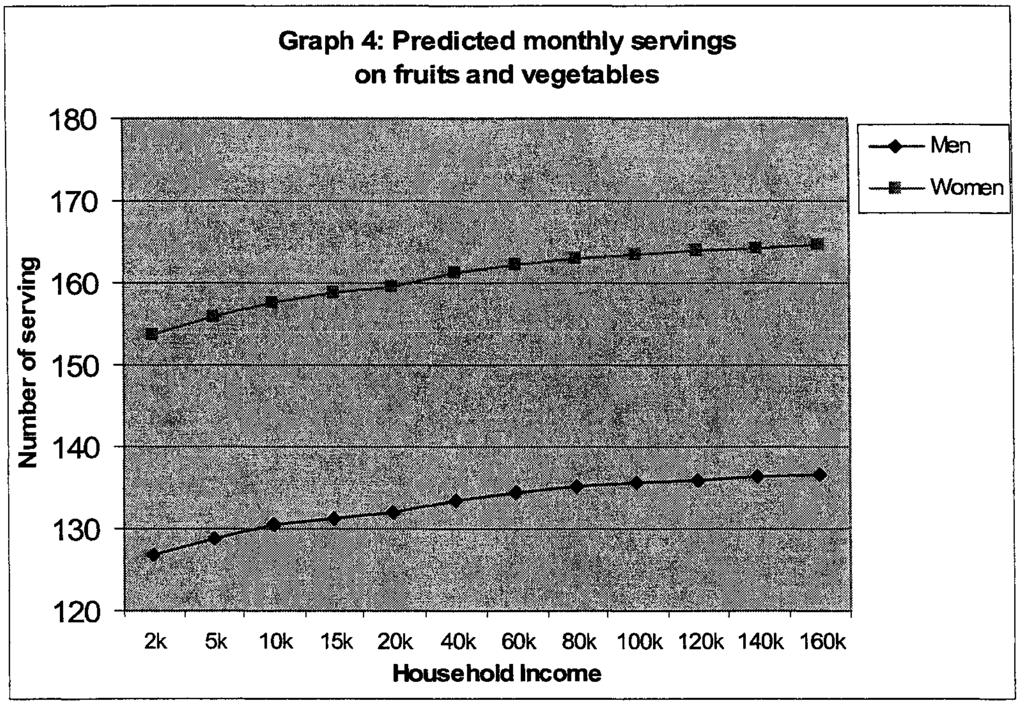
**Table 14 Simulation results of Policy II: Child support policy**

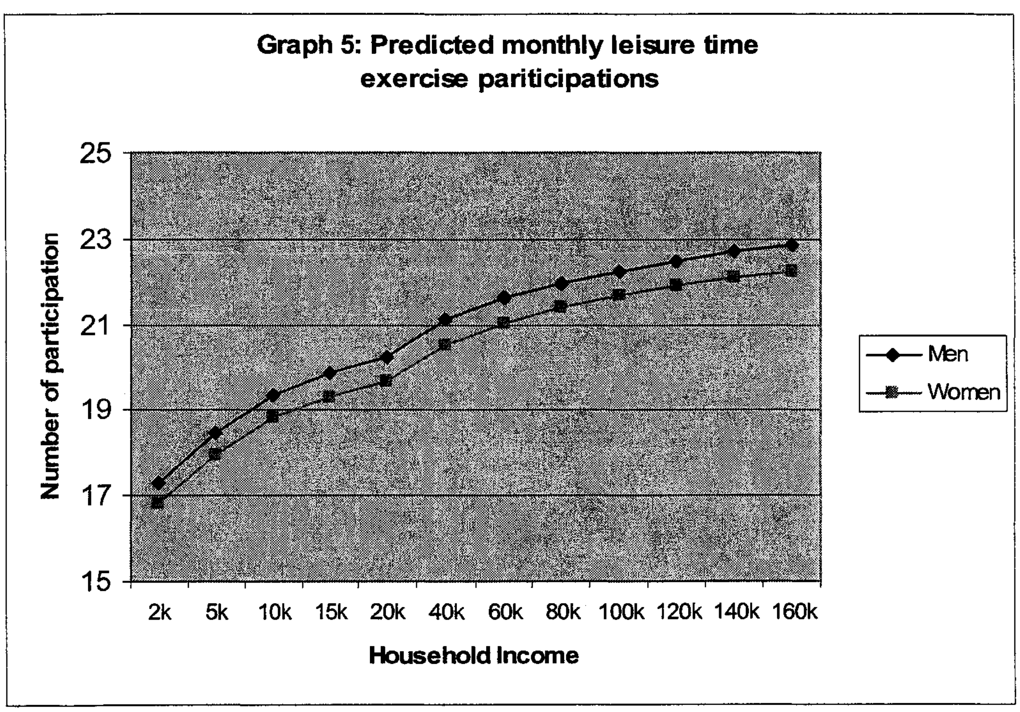
| Men | Women |
|---|---|
| **BEFORE POLICY** | |
| **Probability of being obese** | |
| 14.43% | 18.73% |
| **AFTER POLICY** | |
| **Change in Prob(obs), absolute value** | |
| 0.31% | -2.25% |
| **Change in Prob(obs), relative value** | |
| 2.14% | -12.02% |

**Graph 2 to Graph 5:**




Graph 4: Predicted monthly servings on fruits and vegetables
180
170
160
150
140
130
120
Number of serving
2k 5k 10k 15k 20k 40k 60k 80k 100k 120k 140k 160k
Household Income
Men
Women


Graph 5: Predicted monthly leisure time exercise pariticipations
25
23
21
19
17
15
Number of participation
2k 5k 10k 15k 20k 40k 60k 80k 100k 120k 140k 160k
Household Income
Men
Women

## Appendix A: Description of various calculations contained in chapter 3

**Body Mass Index and Obesity:**

The body mass index (BMI) is calculated as weight in kilograms divided by height in meters squared. It is an index representing the health risk associated with body weight and height. According to the *Canadian Guidelines for Body Weight Classification in Adults,* (Health Canada (2003), the BMI classification in adults can be summarized as follows:

| | |
|---|---|
| Underweight: BMI<18.5 | Normal: 18.5≤BMI<25 |
| Overweight: 25≤BMI< 30 | Obese: BMI≥30 |

**Questions on Fruit and vegetable consumption:**

The nutrition questions in the Canadian Community Health Survey (CCHS) ask about the ***number of times*** any fruits or vegetables are consumed. The frequency of fruit and vegetable consumption is defined by combining all of the information from answers to the following questions:

"1) How often do you usually drink fruit juices such as orange, grapefruit or tomato? (for example, once a day, three times a week, twice a moth)?

2) Not counting juice, how often do you usually eat fruit?
3) How often do you (usually) eat green salad?
4) How often do you usually eat potatoes, not including French fries, friend potatoes, or potato chips?
5) How often do you (usually) eat carrots?
6) Not counting carrots, potatoes, or salad, how many servings of other vegetables do you usually eat?"

**Physical Activities:**

The frequency of all leisure time physical activities is based upon the number of physical activities lasting more than 15 minutes undertaken per month. The monthly frequency variable is calculated using information of respondents' reported leisure-time activities in the previous three months. Only a physical activity lasting over 15 minutes contributes to the frequency calculations.

**Equivalence Scales and Income Quartiles:**

Income equivalence scales allows us to compare the level of household income across households of different sizes by taking into account family size. An appropriate adjustment factor is assigned to each household member. In this chapter I use the 40/30 equivalence scale, originally developed by Statistics Canada, to adjust household income (Barham, Devlin and LaCasse, 2000). In this equivalence scale, the first member is weighted with the factor "1", the second member with the factor 0.4, and the third and subsequent family members are weighted with the factor 0.3. Thus, a family with 3 members and a household income of $45,000 is "equivalent" to a single person with the income $45,000/1.7 = $26,471. This 40/30 scale is used in this chapter to sort "individual equivalent" income into quartiles. The threshold levels for the second, third, and fourth quartile (in thousand dollar of year 2000) are respectively 21.75, 34.8, and 50. We then employed the actual household income reported by the family as the appropriate metric for the analysis.

**Appendix B: Empirical studies related to income, obesity and other health outcomes**

| Literature | Purpose | Data | Methodology | Dependent and independent variables | Major findings on relationship between income and health outcomes (obesity) |
|---|---|---|---|---|---|
| Chou, Grossman and Saffer (2004) | Examine the determinants of adult obesity and related outcome. Find the factors that are responsible for the rapidly increasing obesity prevalence rate. | Behavioral Risk Factor Surveillance System (BRFSS), 1984-1999, 1982, 1987, 1992, and 1997; Census of Retail Trade; Current Population Survey (CPS); | OLS regression on reduced-form determinants of obesity.<br><br>Fit linear probability models rather than logit or probit models. | DV: adjusted BMI and obesity indictor;<br>IV: Household income, income squared, sex, race, education, age, marital status, price of meal in each type of restaurant, price of food consumed at home, price of cigarettes, alcohol price, clean indoor air laws. | Effect of household income on BMI and obesity is negative throughout all the observed income range. The negative effect falls as income rises. |
| Goodman, Slap, and Huang (2003) | Examine the public health impact of the socioeconomic status (SES) gradient on adolescents' physical and mental health. | 1994 household income data; National Longitudinal Study of Adolescent Health. | Calculate population attributable risk (PAR) for household income and parental education relative to depression and obesity among adolescents. Compare PAR indictors in income quintile and parental education categories. | Not Applicable. | The health impact of an exposure on lower income and lower parental duration are both negative and large. Effect of lower parental education was stronger than that of income for both depression and obesity. |

**Appendix B: (Continued)**

| Literature | Purpose | Data | Methodology | Dependent and independent variables | Major findings on relationship between income and health outcomes (obesity) |
|---|---|---|---|---|---|
| Gordon -Larsen, Adair, and Popkin (2003) | To examine the extent to which ethnic differences in income and education account for sex-specific disparities in overweight prevalence in U.S. teens. | National Longitudinal Study of Adolescent Heath Wave II. | Logistic regression to examine the relationship of family income and parental education to overweight prevalence. Use estimated coefficients to project the effects on overweight prevalence of equalizing the socioeconomic status differences between race/ethnic groups. | DV: overweight (BMI≥85%). IV: income, education, ethnicities, Sex, age and pregnancy.<br><br>Use race- and sex-stratified models | Family income and parental education has a limited effect on the disparities on overweight prevalence.<br><br>Ethnicity-SES-overweight differences were greater among females than males. |
| Lakdawa-lla and Philipson (2002) | Tests the hypothesis that technological change has led to weight growth by making home and market-production more sedentary and by lowering food prices through agricultural innovation. | Microdata: National Health Interview Survey (NHIS); National Longitudinal Survey of Youth (NLSY) longitudinal component. | year-specific fixed effect model;<br><br>Employ an instrumental variable approach to identify supply and demand equations for weight. | DV: BMI;<br>IV: year dummies, strength requirement of a worker's job, job strenuousness (on-job exercise), quartile income dummies, age, age square. | Income has the inverted U-shaped effect on the BMI of male workers. Income exerts a consistently negative effect on the BMI of women workers. |

**Appendix B: (Continued)**

| Literature | Purpose | Data | Methodology | Dependent and independent variables | Major findings on relationship between income and health outcomes (obesity) |
|---|---|---|---|---|---|
| Nayga (2000) | Examine how much the relationship between schooling and health (indicated by obesity) can be attributed to differences in health knowledge among individuals. | 1994 Diet and Health Agriculture Knowledge Survey (DHKS) | Two-equation model: 1.Use OLS to predict the diet-disease knowledge variable K. 2. Use ML probit to do parameter estimation, with K and without K respectively. Compare the estimation results with and w/o K. | DV: BMI, Obese, health knowledge; IV: household income, race, age, household size, number of schooling, overall health, sex, employment status, exercise, smoke, special diet, nutrition awareness, view on overweight, personal perception and perceived importance on food guide. | Income measured by actually number (in thousands). Parameters for income are not significant in four estimation equations. Health knowledge is inversely related to the probability that an individual is obese. |
| Ruhm (2000) | Relationship between economic conditions and health. Also examine the relationship regarding tobacco use, obesity, physical activity, and usual check-ups. | State data: aggregate data covering 50 states and district of Columbia for the period of 1972-1991; Microdata: Behavioral Risk Factor Surveillance System (BRFSS) (1987-1995). | (for Microdata only): Fixed-effect model; Linear probability models are displayed for the dichotomous outcomes. Binary probit models estimate virtually identical results. | Related to obesity only: DV: BMI, obese; IV: economic conditions proxies by the average unempl rate and the median of family income of four-person families (actual number, in thousands), Age, education, race, sex, married status. | 1% increase in unemployment associated with a statistically significant .016 reduction in average BMI. (0.6% decline for the sample); coefficients of family income not significant. Mortality is procyclical. Analysis of the BRFSS suggests that this is partially due to decreases in smoking and obesity, improved diets, and increased physical activity. |

**Appendix B: (Continued)**

| **Literature** | **Purpose** | **Data** | **Methodology** | **Dependent and independent variables** | **Major findings on relationship between income and health outcome (obesity)** |
|---|---|---|---|---|---|
| Wang, Patterson, and Hills (2002) | To explore the association between overweight or obese children and household income and parental obesity. | Australian National Nutrition Survey (NUNS).<br><br>Australian National Health Survey (NHS). | Multivariable logistic regression models; Odds ratios on obese children are calculated.<br><br>Household income quintiles were calculated from the midpoint value of income and recoded. | DV: Obese (use International BMI cut-off points);<br>IV: Household income quintiles dummies, age, sex, father's BMI, mother's BMI; | The odds ratio of overweight or obese<br>boys with highest household income was significantly smaller than those with the lowest household income.<br>The proportion of combined overweight and obese children whose parents were overweight or obese was significantly greater compared with those whose parents were not. |
| Zhang and Wang (2004) | To assess socio -economic inequality in the distribution of obesity among adults aged between 18 and 60 in the United States by employing the concentration index (CI). | National Health and Nutrition Examination Survey III, 1988-1994 | Use obesity concentration index (CI) to measure the obesity distribution among income groups. Then stratify the population by gender, age, and ethnicity to estimate the inequality each subgroup. | Not Applicable. | Socioeconomic inequality favors higher SES groups.<br>There is a stronger inverse association between socioeconomic status obesity exits among women than men.<br>Greater socioeconomic inequality exists among middle-aged adults.<br>Remarkable ethnic differences are also found in the relationship. |

**Appendix B: (Continued)**

| Literature | Purpose | Data | Methodology | Dependent and independent variables | Major findings on relationship between income and health outcomes (obesity) |
|---|---|---|---|---|---|
| Averett and Koren-man (1996) | To investigate the difference in income, martial status and hourly pay by body mass. | National Longitudinal Survey of Youth, 1981-1988; Aged 23-31 in 1988 survey; | Multivariate model regression conducted separately by sex and race. | DV: family income, marriage, spouse's earnings, and hourly wages.<br>IV: BMI categories in two periods: 1981 and 1988; control variables include age, education, region, race, SMSA, occupation and actual working experience if employed (for wage regression). | Obese women have lower family income than women in the normal weight range. Results for men are weaker and mixed.<br>With some evidence of labour market discrimination towards obese women, differences in marriage probabilities and spouses' earnings account for about for 50 to 95 percent of their lower economic status. |
| Cawley (2004) | To explain the existing negative relationship between body weight and wages among women, and to generate more consistent estimates of the effect of weight on wage. | National Longitudinal Survey of Youth, 1981-2000(13 years) | 1) OLS estimation;<br>2) OLS with lag weight;<br>3) Individual specific fixed-effects model;<br>4 ) Instrumental variable estimation.<br><br>Regression are estimated separately by sex, race and gender. | DV: LogWage<br>IV: adjusted BMI; adjusted weight in pounds; indictors for underweight, overweight, and obesity; others include age, education, year, marital status, no of children, age of youngest child, general intelligence, education of father and mother, actual working year, county unemployment rate, current school enrolment, part-time job, white collar job, and regions.<br>Instruments:<br>BMI from a sibling | Weight consistently lowers wages for white females.<br>Heavier black males tend to earn more. Unobserved heterogeneity seems to result in heavier black females, Hispanic females, and Hispanic males earning less than lighter counterparts. |

**Appendix B: (Continued)**

| Literature | Purpose | Data | Methodology | Dependent and independent variables | Major findings on relationship between income and health outcomes (obesity) |
|---|---|---|---|---|---|
| Mitra (2001) | To analyze the effects of physical attributes, height and weight, on the wages of males and females in professional and blue-collar occupations. | National Longitudinal Survey of Youth, 1993 | OLS regressions are estimated separately for male and female, and for professionals and Blue-collar workers. | DV: LogWage<br>IV: Height and weight, age marital status, poverty status, education, cognitive skills (math scores), work experience, plant size, father's education, region of residence, whether have children. | Among professionals and blue-collar workers, physical attributes significantly affect the wages of women and have no impact on the wages of men.<br><br>Taller women enjoy wage premiums, and overweight women experience significant wage penalties. |
| Pagan and Davila (1997) | Study the relationship between obesity, occupational attainment, and earnings. | National Longitudinal Survey of Youth, 1989 | Utilize a multinomial logit specification to investigate the occupational selection of obese individuals. Estimate the earnings functions that account for the occupational attainment of the overweighed people. | DV: Log Wages;<br>IV: education, working experience, marital status, race, region of residence, different occupations, BMI, inverse of Mill's ratio (predicted from probit participation equation) | Women pay a penalty for being obese. Men will not due to the low barriers they face when moving across occupations. |

**Appendix B: (Continued)**

| Literature | Purpose | Data | Methodology | Dependent and independent variables | Major findings on relationship between income and health outcome |
|---|---|---|---|---|---|
| Buckley, Denton, Robb, and Spencer (2004) | To examine whether the two socioeconomic factors, income and education, are associated in a causal way with health status as people age. | Survey of Labour and Income Dynamics (SLID) 1994, 1996, 1998 | Draw a sample aged 50 and older and in good health in 1996 survey;<br>Estimated a regression equation on income, and use predicted income quartile in proceeding estimation;<br>Probit model on health status. (individual-specific fixed effect) | DV: health status( good or bad);<br>IV: predicted income quartile, education, age group, marital status, rural/urban.<br><br>Regressions conducted separately for men and women. | Restricting the sample to those in good health initially avoids the endogeneity of health effect on income;<br><br>There is a causal relationship running from family income and education to health status among older Canadians. |
| Dooley and Stewart (2004) | To estimate the existence and size of the causal effect of income on child outcomes measured by cognitive abilities. | Canadian National Longitudinal Survey of Children and Youth (NLSCY) | Five strategies: 1) Conventional OLS; 2) Fixed-effects model; (child-specific and family-specific) 3) consumption activities pathway; 4) income before and after an outcome;<br>5) welfare income; | DV: three measures of cognition;<br>IV: log average income, lone mother, two parents , dummies for families with certain age of children, number of children, mother's education, mother' age>34. | The tests provide support for the claim that the true effect of income on children outcomes may indeed be positive, but that it is also likely to be smaller than the conventional estimates. |

**Appendix B: (Continued)**

| Literature | Purpose | Data | Methodology | Dependent and independent variables | Major findings on relationship between income and health outcome |
|---|---|---|---|---|---|
| Ettner (1996) | Estimate the structural impact of income on some measures of health. | National survey of family and household; Survey of income and program participation; National health interview survey. | Ordinary estimation by Ordered probit; Probit; Two-part model;<br><br>Two-stage probit regression when instrumental variables are added. | DV: self-assessed health status, work and functional limitation, bed days, average alcohol consumption, and depressive symptoms.<br>IV: income of person and spouse, sex, marital status, household size, children, education, race, parents' education, state unemployment rate, spouse's education, working experience. | The effect of income remains significant and actually increases in magnitude with the IV estimation.<br><br>Increase in income significantly improves mental and physical health, but increases the prevalence of alcohol consumption. |
| Meer, Miller, and Rosen (2003) | Use heritance as a new instrument variable to estimate the impact of wealth on individual's health status, and to verify the causal link between wealth and health. | Panel Study of Income Dynamics 1984, 1989, 1994, 1999 | Ordinary estimation by basic probit model;<br><br>Two-stage probit model when instrumental variable is considered. | DV: dichotomous variable indicating healthy or not derived from self-reported health status.<br>IV: age, education, sex, ethnicity, region, marital status, whether having children, wealth, and inheritance (instrument) | Instrumental variables point estimators are even larger than ordinary estimators, but not significantly different from zero.<br><br>Wealth-health connection is not driven by short run changes in wealth. |

**Appendix C: First stage regression results on log income and related statistics**

| Variables | Men | | Women | |
|---|---|---|---|---|
| | Coef | t-value_rb | Coef | t-value_rb |
| Intercept | 9.5802 | 111.54 | 9.2903 | 108.66 |
| Hhighschool | 0.2191 | 7.15 | 0.2033 | 5.97 |
| Hcollege | 0.3010 | 9.53 | 0.3093 | 7.74 |
| Huniversity | 0.4550 | 10.23 | 0.5121 | 12.65 |
| Urate | -0.0066 | -3.22 | -0.0067 | -3.70 |
| Dwelling owned | 0.2952 | 14.61 | 0.3367 | 21.39 |
| Bedroom | 0.0984 | 10.25 | 0.0682 | 10.60 |
| Dividend and interest | 0.2236 | 15.38 | 0.2115 | 16.35 |
| Age | 0.0168 | 4.25 | 0.0246 | 5.47 |
| Agesq | 0.0003 | -5.99 | -0.0004 | -7.11 |
| Hhsize | 0.0512 | 6.29 | 0.0614 | 5.55 |
| Children | -0.1647 | -9.13 | -0.1562 | -9.54 |
| Married | 0.2398 | 13.74 | 0.3632 | 21.33 |
| Highschool | 0.1101 | 4.13 | 0.1046 | 3.40 |
| College | 0.1056 | 3.82 | 0.1193 | 3.27 |
| University | 0.2139 | 4.98 | 0.1924 | 4.80 |
| CMA | 0.1614 | 15.22 | 0.1752 | 16.89 |
| Atlantic | -0.2457 | -12.21 | -0.2282 | -12.75 |
| Prairie | -0.1088 | -6.76 | -0.1063 | -7.19 |
| BC | -0.0996 | -4.38 | -0.0776 | -4.49 |
| Que | -0.1463 | -9.34 | -0.1420 | -8.72 |
| Asian | -0.3107 | -9.98 | -0.2974 | -9.48 |
| Black | -0.0975 | -2.51 | -0.2088 | -4.62 |
| Aborig | -0.2324 | -4.31 | -0.1642 | -4.05 |
| Latin | -0.4945 | -2.80 | -0.0750 | -0.89 |
| Other | -0.2403 | -4.60 | -0.3796 | -2.61 |
| Imm<5 | -0.5633 | -6.43 | -0.5775 | -7.34 |
| 5≤Imm<10 | -0.1990 | -3.54 | -0.3318 | -4.59 |
| Heavy drinker | 0.0793 | 3.67 | 0.0713 | 2.95 |
| Former drinker | -0.0682 | -3.11 | -0.1734 | -4.43 |
| Smoker | -0.0729 | -4.99 | -0.0465 | -3.49 |
| Former smoker | -0.1435 | -0.98 | 0.0058 | 0.06 |
| Workhour | 0.0022 | 9.28 | 0.0024 | 8.15 |
| Act restriction | -0.1154 | -8.75 | -0.1295 | -9.82 |
| Standwork | -0.0648 | -3.58 | -0.1114 | -7.73 |
| Lightwork | -0.0443 | -2.50 | -0.1333 | -8.27 |
| Heavywork | -0.0333 | -1.75 | -0.0749 | -3.46 |
| R-square | 0.2010 | | 0.2471 | |
| Sample size | 57,813 | | 59,336 | |

Note: The critical values for the estimated coefficients to be significant at 10%, 5%, and 1% level are respectively 1.645,1.960, and 2.576

**Appendix C: (Continuted)**

| Variables | Men | | Women | |
|---|---|---|---|---|
| **F-statistics in the first stage with robust standard errors for each group of instruments** | | | | |
| Hhighschool=Hcollege=Huniversity=0 | 112.12 *** | | 206.62 *** | |
| Unemployment rate=0 | 10.34 *** | | 13.72 *** | |
| Dwelling owned=bedroom=0 | 560.88 *** | | 765.9 *** | |
| Dividend and interest=0 | 236.44 *** | | 267.18 *** | |
| **F-statitics and t-statistics in the second stage: OLS regression on BMI** | | | | |
| | **t-stat** | **F-stat** | **t-stat** | **F-stat** |
| Hhighschool | 1.72 * | | 0.86 | |
| Hcollege | 1.47 | 21.41 *** | 1.18 | 20.44 *** |
| Huniversity | 0.89 | | 1.23 | |
| Uemployment rate | | 0.09 | | 0.71 |
| Dwelling owned | 1.10 | 13.37 *** | 1.62 * | 21.84 *** |
| bedroom | 3.42 *** | | 4.46 *** | |
| Dividend and interest | | 4.55 ** | | 3.24 * |
| **Wald-statitics in the second stage: Probit regression on obesity** | | | | |
| | **Single** | **Joint** | **Single** | **Joint** |
| Hhighschool | 0.05 | | 0.16 | |
| Hcollege | 0.11 | 17.90 *** | 0.10 | 12.30 *** |
| Huniversity | 0.47 | | 0.69 | |
| Uemployment rate | | 0.20 | | 0.97 |
| Dwelling owned | 4.81 ** | 32.66 *** | 0.89 | 9.63 *** |
| bedroom | 31.90 *** | | 9.45 *** | |
| Dividend and interest | | 20.63 *** | | 0.7561 |
| Sample size | 57,813 | | 59,336 | |

Note: *Denotes that the associated statistic is significant at 10% level.
**Denotes that the associated statistic is significant at 5% level.
***Denotes that the associated statistic is significant at 1% level.

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