Uncertainty, the Demand for Health Care, and Precautionary Saving

Diego Nocetti∗  William T. Smith†

∗Clarkson University, dnocetti@clarkson.edu
†University of Memphis, wsmith@memphis.edu

Recommended Citation
Available at: http://www.bepress.com/bejeap/vol10/iss1/art75

Copyright ©2010 The Berkeley Electronic Press. All rights reserved.
Uncertainty, the Demand for Health Care, and Precautionary Saving*

Diego Nocetti and William T. Smith

Abstract

We analyze the demand for medical care and precautionary saving in a framework with uncertainty surrounding the incidence of illness and the effectiveness of medical treatments and a representation of preferences that disentangles ordinal preferences, risk preferences, and intertemporal smoothing preferences. We consider a “pure consumption” model with exogenous health capital and a model where young consumers invest in preventive care to increase their future health stock. In both cases, we establish conditions for the different sources for uncertainty to induce precautionary saving and we evaluate how uncertainty affects the demand of curative and preventive care. We also show that given the self-insurance function of preventive care, consumers’ welfare may increase with the degree of uncertainty surrounding health care effectiveness.

KEYWORDS: health uncertainty, demand for health care, preventive care, precautionary saving, risk aversion, intertemporal substitution

*We thank the editor Nolan Miller and two anonymous reviewers for very helpful comments and suggestions.
1. Introduction

Uncertainty is one of the defining characteristics of the demand for health care goods and services (Arrow, 1963). Consumers, for example, are subject to random shocks to their health, they lack the information to accurately diagnose their health, and they face uncertainty surrounding the effectiveness of health-care treatments (e.g. van Doorslaer, 1987; Dardanoni and Wagstaff, 1990). It is reasonable to presume that consumers respond to these uncertainties by adjusting their patterns of consumption and health care purchases over their life-cycle. One may expect, for instance, that consumers display some form of precautionary behavior in response to uncertainty.

If health care expenditures were exogenous to the consumer, uncertainty surrounding those expenditures would translate into income uncertainty and the standard theory of precautionary saving (e.g. Leland, 1968; Sandmo, 1970; Kimball, 1990) would apply. This is the assumption implicit in most empirical papers that look for a link between uncertainty surrounding health care expenditures and saving behavior (e.g. Kotlikoff, 1989; Hubbard et al. 1995; Star-Maccluer, 1996; Gruber and Yelowitz, 1999; Palumbo, 1999; Chou et al. 2003; Dynan et al. 2004, Japelli et al 2007, Love et al. 2009).

The standard theory of precautionary saving, however, provides an incomplete description of how consumers respond to uncertainty. First, if individuals can adjust their demand for health care in response to uncertainty surrounding the effectiveness of medical treatments then the degree of uncertainty itself becomes endogenous. As a result, precautionary saving may behave differently than in a model with exogenous health expenditures. Second, in addition to - or instead of - buying assets in financial markets, consumers may display precautionary behavior by buying preventive care; they may invest in health care when young in order to increase their future health stock. Third, if preferences are defined over both health and consumption of goods, then – in a world with uncertainty -- the shape of the utility function governs both risk preferences and ordinal preferences over the two goods. It becomes necessary to define multi-commodity measures of risk. Finally, and not unique to models of health care demand, the standard theory of precautionary saving, which is based on intertemporal expected utility maximization, does not distinguish between preferences towards risk and preferences towards intertemporal smoothing, which is of critical importance given the dynamic aspect of saving (Kimball and Weil, 2009).

In this paper we develop a simplified, stochastic version of Grossman’s (1972) health capital model to analyze the demand for health care and precautionary saving behavior in a framework with two features: (1) uncertainty surrounding the incidence of illness and the effectiveness of health care
expenditures and (2) a representation of preferences that disentangles attitudes towards risk, attitudes towards intertemporal substitution, and ordinal preferences for consumption-goods and health.

We consider initially a ‘pure consumption’ model with exogenous health capital. We interpret the demand for medical care in this model as representing purchases of medical goods for non-preventable diseases. We show that, under mild assumptions, consumers will save more as a precaution when they face uncertainty surrounding the incidence of illness. They do so by sacrificing some consumption and health when young. With uncertainty surrounding the effectiveness of future medical care, ordinal preferences and attitudes towards risk and intertemporal smoothing interact to determine whether the consumer saves more. Under plausible assumptions on risk and ordinal preferences, only consumers that are highly averse to intertemporal fluctuations save more and purchase less medical care when young.

Then, we extend the model to incorporate the possibility of investments in health capital with purchases of preventive care, which may also have uncertain effectiveness. In the presence of uncertainty, younger consumers purchase additional medical care as a form of self-insurance. We analyze precisely what determines the demand for preventive care, curative care, and savings. We show that, if the accumulation of health capital is relatively safe (when compared with future medical care), consumers that are highly averse to intertemporal fluctuations save less when there is uncertainty.

Finally, we evaluate the effect of medical care uncertainty on consumer’s welfare. We show that consumers may gain from variability in medical care effectiveness. Intuitively, when preventive care effectiveness is fairly certain consumers can (better) self-insure against future medical care risk. Given this insurance, consumers expect to benefit from high realizations of medical treatment effectiveness while maintaining a good level of health if treatment effectiveness is low. Therefore, public policies that reduce the variability of medical treatments (e.g. stricter drug approval rules) may also reduce consumers’ welfare.

Our analysis is most closely related to the work of Dardanoni and Wagstaff (1990). Dardanoni and Wagstaff evaluate the effects of uncertainty

---

1 Other papers are closely related as well. Picone et al (1998) solve numerically a life cycle model with an endogenous accumulation of wealth and of health capital. We explore these extensions theoretically in a two-period model with a more general specification of preferences. Levin (1995) analyzes the joint determination of health insurance and savings in a model where health is not an argument of the utility function. Another line of research (Dardanoni and Wagstaff, 1987; Selden, 1993; Chang, 1996) considers the effect of health uncertainty on the demand for health care within a pure investment model. The focus on those papers is on the effect of initial wealth on the demand for health care. Koc (2004 a) evaluates the effect of uncertainty on the demand for health care.
surrounding the incidence of illness and health care effectiveness in a static framework in which individuals select the level of (preventive) care before the realization of shocks. They provide sufficient conditions for uncertainty to increase medical care expenditures in terms of the partial derivatives and cross partial derivatives of a utility function of the form \( U(\text{consumption}, \text{health}) \). Eeckhoudt et al. (2007) suggest an interpretation for the signs of those cross partial derivatives. This interpretation, however, is clouded by the fact that the shape of the utility function governs both risk and ordinal preferences. We use the methods developed by Khilstrom and Mirman (1974, 1981) to disentangle those distinct aspects of preferences and we extend these methods to an intertemporal framework where we use the preference structure proposed by Selden (1978, 1979) to disentangle risk preferences from intertemporal smoothing preferences. Our results show that the separation of the different aspects of preferences is critical for understanding how uncertainty affects medical care demand over the life cycle and saving.

Our analysis is also closely related to the existing literature on precautionary saving. We show that, conditional on the optimal demand of consumption goods and medical care, uncertainty surrounding the incidence of illness is equivalent to a problem with income uncertainty, while uncertainty surrounding medical care effectiveness is equivalent to a problem with interest rate risk. This allows us to analyze health and health-care uncertainty using well known results about precautionary saving under income uncertainty (e.g. Leland, 1968; Sandmo, 1970; Kimball, 1990; Kimball and Weil, 2009) and under interest rate uncertainty (e.g. Rothschild and Stiglitz 1971; Selden, 1979).

The rest of the paper proceeds as follows. In section 2 we present the model with exogenous health capital. Section 3 evaluates the effect of uncertainty on consumer’s choices of saving and medical care expenditures. In section 4 we extend the model to incorporate purchases of preventive care and, within this model, we evaluate the welfare effects of medical care uncertainty. Section 5 summarizes the results and presents some policy implication.

2. The Model

We analyze a model in which a representative consumer lives for two periods. The consumer receives a non-stochastic wage \( w \) each period, purchases medical care and a composite consumption basket \( m_i, c_i, i = 1, 2 \), and saves an amount \( s \).
2.1. Budget Constraints and Technology

For simplicity we assume that the relative price of medical care \( p \) is constant and that the market rate of return on savings is zero. The price \( p \) can be interpreted as the co-insurance rate, or the fraction of medical care paid out-of-pocket given an insurance policy. The budget constraints are then,

\[
\begin{align*}
c_1 + pm_1 &= w - s \quad (1) \\
c_2 + pm_2 &= w + s. \quad (2)
\end{align*}
\]

As in Dardanoni and Wagstaff (1990), health at time \( i, h_i \) is linear in the current level of medical care purchased:

\[
h_i = \chi_i + \mu_i m_i. \quad (3)
\]

\( \chi_i, i = 1,2 \) represents the health endowment (or health capital or the basic level of health) at time \( i \) while \( \mu_i \) determines the efficiency of medical treatments at time \( i \). \( \chi_1 \) and \( \mu_1 \) are known at the time consumption, medical care, and savings are selected in the first period. However, at this time, \( \chi_2 \) and \( \mu_2 \) are uncertain (but known when second period consumption and medical expenditures are chosen). We assume that \( \chi_2 = \bar{\chi}_2 + \xi_\chi \), where \( \xi_\chi \) is a mean zero random variable with variance \( \sigma_\chi^2 \geq 0 \). We will refer to the level of \( \sigma_\chi^2 \) as ‘health risk’. Presumably \( \bar{\chi}_2 < \chi_1 \), due to deterministic depreciation of health stock over time. In Section 4 we consider the case in which \( \chi_2 \) is determined endogenously by investments in preventive care. We also assume that \( \mu_2 = \bar{\mu}_2 + \xi_\mu \), where \( \xi_\mu \) is a mean zero random variable with variance \( \sigma_\mu^2 \geq 0 \). We will call the level of \( \sigma_\mu^2 \) ‘medical care risk’. We will generally assume that \( \bar{\mu}_2 = \mu_1 = \mu \).

It will facilitate interpretation of the model later to consolidate Equations (1), (2), and (3) into a single budget constraint for each period:

\[
\begin{align*}
c_1 + \frac{p}{\mu_1} h_1 + s &= w + \frac{p}{\mu_1} \chi_1 = z_1 \\
c_2 + \frac{p}{\mu_2} h_2 - s &= w + \frac{p}{\mu_2} \chi_2 = z_2.
\end{align*}
\]

---

\( ^2 \) This specification leaves open the possibility that health could be negative. Finding solutions with a “liquidity” constraint is challenging and possibly important (see e.g. Deaton1991 and Zeldes, 1989). Future research should investigate the robustness of our results to incorporating this constraint and to using more general health production functions.

http://www.bepress.com/bejeap/vol10/iss1/art75
The left-hand side of each of these equations is total expenditure on consumption and medical care in the relevant period. The right-hand side, $z_i$, is Gary Becker’s “full income,” the maximum income that could be earned in the period assuming the consumer enjoyed no leisure. In this case full income is adjusted to include the value of the endowment of health, $\frac{p}{\mu_i}x_i$. Notice that $\frac{p}{\mu_i}$ is the relative price of health capital. \(^3\)

2.2. Preferences

Following Nocetti and Smith (2010), we consider a specification of utility that disentangles risk aversion, aversion towards fluctuations in consumption and health over time, and ordinal preferences over consumption and health. The utility function is

$$u[f(c_1,h_1)] + u\{v^{-1}[Ev[f(c_2,h_2)]]\].$$ (5)

We assume that $f(\cdot)$ is linearly homogeneous, with positive and diminishing marginal utilities, $f_c > 0, f_h > 0, f_{cc} < 0, f_{hh} < 0$, and that the functions $u(\cdot)$ and $v(\cdot)$ are monotonically increasing and concave: $v'>0, v''<0, v'>0, v''<0$.

The pure rate of time preference is assumed to be zero (equal to the market rate of interest). The qualitative results do not depend in any way on the assumption of no time discounting.

Since the function $f(\cdot)$ is linearly homogeneous and the function $v(\cdot)$ is monotone increasing, it follows that $V(c_2,h_2) = v[f(c_2,h_2)]$ is a homothetic function of $c_2$ and $h_2$. Therefore, following Khilstrom and Mirman (1974, 1981), we can interpret $f(\cdot)$ as governing ordinal preferences over the different goods and the function $v(\cdot)$ as governing atemporal risk preferences. Alternatively, we can think of the curvature of $v(\cdot)$ as determining risk aversion with respect to the “aggregator” $f(\cdot)$. Since $v(\cdot)$ governs risk aversion, we will refer to $A = -v''/v'$ as absolute risk aversion and to $R(f) = -v''/f/v'$ as relative risk

\(^3\) In the literature $p/\mu$ is often called a “shadow price,” since $\mu$ is not determined in a market. However, since the term “shadow price” normally is a synonym for a Lagrange multiplier we will avoid confusion by simply referring to $p/\mu$ as a relative price.

\(^4\) Kihlstrom and Mirman (1981 p.272) argued that, to properly define the concepts of constant, decreasing, and increasing risk aversion in a multi-dimensional framework, it is necessary to “compare the risk averseness of the utility function at two points only if there is an appropriate sense in which the ordinal preferences represented by the utility function are the same at each of the two is points.” The assumption of homothetic preferences, which implies that the marginal rate of substitution is constant, achieves this objective. Of course, the assumption is also convenient, but quite restrictive.
aversion. Following Kimball and Weil (2009) we will call $\varepsilon(f) = -A / f$ the elasticity of risk tolerance. We also define the function $M = v^{-1}[Ev[f(c_2, h_2)]]$. This is the certainty-equivalent ordinal utility in the second period.

To disentangle risk aversion from aversion to intertemporal fluctuations we use the ordinal-certainty-equivalent representation of Selden (1978, 1979). Specifically, since $u(\cdot)$ is a monotone transformation of the linearly homogeneous function $f(\cdot)$ in each period, $U(c_i, h_i) = u[f(c_i, h_i)]$, $i = 1, 2$ is a homothetic function of $c_i$ and $h_i$. The function $u(\cdot)$ governs the willingness to substitute intertemporally between the aggregators $f(c_1, h_1)$ and $M$. In other words, the curvature of $u(\cdot)$ reflects preferences between riskless ordinal utilities over time. We will refer to $\phi = -u'/fu''$ as the elasticity of intertemporal substitution and to $1/\phi$ as the measure of aversion to intertemporal fluctuations.

Two examples of our preference structure, which we will use later, are constant relative risk aversion and constant elasticity of intertemporal substitution

$$u[f(c_1, h_1)] + u[v^{-1}[Ev[f(c_2, h_2)]]] = \frac{(f(c_1, h_1))^{1-\rho}}{1-\rho} + \frac{[Ev[f(c_2, h_2)]^{1-\gamma}]^{1-\rho}}{1-\rho}, \quad (6)$$

and constant absolute risk aversion and constant elasticity of intertemporal substitution

$$u[f(c_1, h_1)] + u[v^{-1}[Ev[f(c_2, h_2)]]] = \frac{(f(c_1, h_1))^{1-\rho}}{1-\rho} + \frac{[-ln[Ev[e^{-\alpha f(c_2, h_2)}]]^{1-\rho}}{1-\rho}. \quad (7)$$

2.3. The Consumer’s Problem

The consumer chooses $c_1, h_1, c_2, h_2$, and $s$ in order to maximize Eq. (5) given the temporal budget constraints (1) and (2) and the consolidated budget constraints in Equations (4). We emphasize that $c_2$ and $h_2$ are chosen after the realization of uncertainty.

It is convenient to solve this problem by decomposing it into two parts:

1. Maximize utility in each period given savings

$$\max_{c_1, h_1} f(c_1, h_1) \text{ s.t. } c_1 + \frac{p}{\mu_1} h_1 = z_1 - s \quad (8)$$

$$\max_{c_2, h_2} f(c_2, h_2) \text{ s.t. } c_2 + \frac{p}{\mu_2} h_2 = z_2 + s,$$
where \( z_1 = w + \frac{p_{\mu_1}}{\mu_1} \chi_1 \) and \( z_2 = w + \frac{p_{\mu_2}}{\mu_2} \chi_2 \) are full income in the first and second periods. Notice that the consumer knows the realizations of the two shocks before he makes his choices of consumption and health in the second period. Therefore there is no uncertainty in this stage of the problem and \( v^{-1}[Ev[f(c_2, h_2)]] = f(c_2, h_2) \).

It is well known that if preferences are homothetic then Marshallian demands are proportional to income. This implies that in our setting they are of the form

\[
c_1^* = g_c \left( \frac{p}{\mu_1} \right) (z_1 - s),
\]

\[
h_1^* = g_h \left( \frac{p}{\mu_1} \right) (z_1 - s)
\]

\[
c_2^* = g_c \left( \frac{p}{\mu_2} \right) (z_2 + s),
\]

\[
h_2^* = g_h \left( \frac{p}{\mu_2} \right) (z_2 + s),
\]

for some functions \( g_c \left( \frac{p}{\mu_i} \right) \) and \( g_h \left( \frac{p}{\mu_i} \right) \).

Using the health production function in Equations (3), we can then back out the demands for medical care:

\[
m_1^* = g_h \left( \frac{p}{\mu_1} \right) \frac{X_1 - s}{\mu_1},
\]

\[
m_2^* = g_h \left( \frac{p}{\mu_2} \right) \frac{X_2 + s}{\mu_2}.
\]

Finally, the resulting period indirect utility functions are also proportional to income and can be written as

\[
\bar{f} \left( \frac{p}{\mu_1}, w, \chi_1, s \right) = \kappa \left( \frac{p}{\mu_1} \right) (z_1 - s),
\]

\[
\bar{f} \left( \frac{p}{\mu_2}, w, \chi_2, s \right) = \kappa \left( \frac{p}{\mu_2} \right) (z_2 + s).
\]

2. Choose savings to maximize lifetime utility

Substituting the indirect utility functions from the two static problems (Eqs. 11) into the lifetime utility function in Eq. (5) yields the optimization problem

\[
\max_s u \left[ \kappa \left( \frac{p}{\mu_1} \right) (z_1 - s) \right] + u \left[ v^{-1} \left[ Ev \left[ \kappa \left( \frac{p}{\mu_2} \right) (z_2 + s) \right] \right] \right].
\]

The first-order condition for this problem is

\[
u' \left[ \kappa \left( \frac{p}{\mu_1} \right) z_1 \right] \kappa \left( \frac{p}{\mu_1} \right) = u' [M(s)] M'(s),
\]
where

\[ M'(s) = v^{-1'} \left[ E v \left[ \kappa \left( \frac{p}{\mu_2} \right) (z_2 + s) \right] \right] E v' \left[ \kappa \left( \frac{p}{\mu_2} \right) (z_2 + s) \right] \kappa \left( \frac{p}{\mu_2} \right) = \]

\[ E v' \left[ \kappa \left( \frac{p}{\mu_2} \right) (z_2 + s) \right] \kappa \left( \frac{p}{\mu_2} \right). \]

\( M'(s) \) reflects the marginal effect of savings on the certainty-equivalent ordinal utility in the second period. Eq. (13) implicitly determines the optimal saving rate, \( s^* \). In the following sections we analyze the properties of the saving rate and medical expenditures with health and medical care risk.

3. Risk, Saving, and Medical Expenditures

We are now equipped to analyze how uncertainty affects consumer’s choices of saving and medical expenditures. We will tackle this question sequentially, first dealing with the case where there is only uncertainty about exogenous health capital, and then with the case where there is only uncertainty about the effectiveness of medical expenditures. Although we focus on small risk approximations to provide a more intuitive exposition, in an appendix, available upon request, we show that the results in the propositions also hold under large risks.

3.1. Health Risk

First consider a world with “pure” health risk: There is uncertainty about exogenous health capital, \( \chi_2 \), but the productivity of medical care is known with certainty, so \( \sigma_\mu^2 = 0 \) and \( \sigma_\chi^2 > 0 \). In Appendix A.1 we show that the optimal level of savings can be approximated by

\[ s^* = \bar{s} + A \kappa \left( \frac{p}{\mu} \right) (1 + \phi \varepsilon) \left( \frac{p}{\mu} \right)^2 \frac{\sigma_\chi^2}{4}, \]  

or equivalently,

\[ s^* = \bar{s} + R (1 + \phi \varepsilon) \left( \frac{p}{\mu} \right)^2 \frac{\sigma_\chi^2}{4}, \]  

where \( \bar{s} = \frac{1}{2} \frac{p}{\mu} (\chi_1 - \chi_2) \) is the saving rate that the consumer would select under certainty due to the expected depreciation of the initial health capital that occurs
with age and \( Z = \bar{z}_2 + \bar{s} = z_1 - \bar{s} = w + (1/2)(p/\mu)(\chi_1 + \chi_2) \) is full income adjusted for saving. This means that – as always under certainty when the rate of time preferences equals the rate of return -- the consumer selects a flat expenditure profile: full income, adjusted for saving, in each period equals half of his lifetime wealth (human and health capital).

On inspection, a sufficient condition for the second term in Eq. (14) to be positive is that \( \varepsilon > 0 \). Since \( \varepsilon(f) = -A/f/A \), decreasing absolute risk aversion (DARA), \( A/ = (-v'/v')' < 0 \), implies \( \varepsilon > 0 \). Furthermore, we know from Equations (9) that the first and second period demands for medical care, \( m_1^* \) and \( m_2^* \), are decreasing and increasing, respectively, in the saving rate. This implies

**Proposition 1.** If preferences exhibit decreasing absolute risk aversion, then an increase in health risk will

- increase savings,
- decrease first period medical expenditures, and
- increase expected second period medical expenditures.

Intuitively, an increase in uncertainty about the basic level of health has an effect that is equivalent to an increase in income uncertainty. As shown by Kimball and Weil (2009) in the case of a single commodity and by Nocetti and Smith (2010) for the case of multiple commodities (leisure and consumption), when there is income risk DARA is sufficient for prudent behavior even when risk and intertemporal smoothing preferences are separated (both under small and large risks).

In fact, DARA implies that prudence is stronger than risk aversion, in the sense that the precautionary premium (the amount of certain income that the consumer would require to save the same amount under uncertainty as if there were no uncertainty) is larger than the risk premium if this condition is satisfied. Drèze and Modigliani (1972) proved this result in a framework with intertemporal expected utility while Kimball and Weil (2009) proved it for the more general Selden preferences. They referred to the incentive to save beyond what one would expect from the reduction of utility as a substitution effect. In the present model, this substitution effect is given by \( R\phi\epsilon \frac{1}{Z} \frac{2}{\mu} \frac{\sigma^2}{4} \).

The substitution effect is the key difference between a model with intertemporal expected utility and our model with Selden preferences. Eq. (14) tells us that, for a given level of \( \varepsilon \) (e.g. under constant relative risk aversion in which case \( \varepsilon = 1 \)), savings increase when consumers become more averse to risk. This is not surprising. Eq. (14) also implies that the Drèze -Modigliani substitution effect increases with the elasticity of intertemporal substitution. In
other words, given DARA, consumers save more if they are less averse to intertemporal fluctuations. This is because the extra-saving induced by DARA shifts resources from the present to the future. Consumers that are less averse to intertemporal fluctuations will also care less about this shift of resources, so they will save more. In an intertemporal expected utility framework, which imposes the restriction $R = 1/\phi$, we would instead conclude that savings increase when consumers become more averse to risk or more averse to intertemporal fluctuations.

In a static model in which medical expenditures are chosen before the realization of uncertainty, Dardanoni and Wagstaff (1990) showed that consumers chose to spend more as a precaution against a low realization of the health endowment (i.e. sickness). In our dynamic framework, consumers also chose to spend more (in expectation) as a precaution, but they do so by sacrificing some consumption and health in the first period.

As an example, suppose that preferences have constant relative risk aversion and constant elasticity of intertemporal substitution, as in Eq. (6), and that the aggregator $f$ is Cobb-Douglas, $f(c_i, h_i) = c_i^{1-b}h_i^b$. The Marshallian demands for medical care in the two periods [from Eq. (10)] are

$$m_1^* = b \frac{w-s}{p} - (1 - b) \frac{\chi_1}{\mu}$$ and $$m_2^* = b \frac{w+s}{p} - (1 - b) \frac{\chi_2}{\mu_2},$$ (15)

and the local approximation of the saving rate is

$$s = \frac{1}{2} \frac{p}{\mu} (\chi_1 - \chi_2) + \gamma \left[ 1 + \frac{1}{\rho} \right] \left( \frac{p}{\mu} \right)^2 \frac{\sigma^2}{4}.$$ (16)

Since constant relative risk aversion implies DARA, in this case Proposition 1 always holds: an increase in health risk unambiguously raises saving, reduces medical expenditures in the first period, and raises them (in expectation) in the second. Eq. (16) further reveals that the effect of an increase in risk will be of larger magnitude for those individuals (1) who are more risk averse, (2) who care less about intertemporal smoothing, and, (3) who have lower income and or lower health endowments (i.e. those more likely to get sick).

An increase in the relative price of health (i.e. lower treatment effectiveness or a higher price of medical treatments –higher co-insurance rate)

---

5 We should note that Dardanoni and Wagstaff’s definition of prudence is different to ours. Using a utility function of the form $U(c, h)$ what they showed is that medical expenditures increase with health uncertainty if $-U_{122} + U_{222} > 0$. This imposes restrictions on risk preferences as well as on ordinal preferences. We showed that, if preferences are homothetic, it is only risk preferences what matters to sign the effect of such uncertainty.
also increases precautionary saving and the effect of health risk. Therefore, for example, more generous public insurance programs, which reduce the effective degree of uncertainty (by reducing the price of medical care), will tend to reduce the precautionary saving motive, increase current expenditures (including current medical expenditures) and reduce future expected expenditures. This is consistent with the empirical findings of Gruber and Yelowitz (1999), who find the Medicaid eligibility reduces wealth holdings, and of Chou et (2003), who find that the introduction of National health insurance in Taiwan reduced household saving [see, however, Starr-McCluer (1996)]. Our analysis also provides a framework for interpreting the results of Japelli et al (2007), who found that the interaction of lower quality of health care and higher health risk induce consumers to save more.

If we instead assume that preferences have constant absolute risk aversion and constant elasticity of intertemporal substitution, as in Eq. (7), we can obtain an exact solution for the saving rate,

\[
s = \frac{1}{2} \frac{p}{\mu} (\chi_1 - \bar{x}_2) + \alpha \kappa \left( \frac{p}{\mu} \right) \left( \frac{p}{\mu} \right)^2 \frac{\sigma^2}{4}.
\]

(17)

As implied by (14), when absolute risk aversion is constant preferences for intertemporal substitution do not affect precautionary saving (the Drèze - Modigliani substitution effect disappears), but ordinal preferences do (through the function \( \kappa \left( \frac{p}{\mu} \right) \)).

3.2. Medical Care Risk

Now consider the effects of “pure” medical care risk: There is uncertainty about the effectiveness of medical care, \( \mu_2 \), but the level of health capital is known with certainty, so \( \sigma^2 = 0 \) and \( \mu > 0 \). We assume, as Dardanoni and Wagstaff (1990) did, that \( \chi_2 = 0 \), so the second period health production function takes the form \( h_2 = \mu_2 m_2 \). In this case, the demands for medical care are given by Equations (10) with \( \chi_2 = 0 \) and a small risk approximation of optimal saving yields (see Appendix B)

---

6 A more generous public insurance not only affects precautionary saving but it also affects saving under certainty. In particular, since \( \bar{s} = \frac{1}{2} \frac{p}{\mu} (\chi_1 - \bar{x}_2) \), a more generous insurance decreases saving under certainty provided that health capital depreciates with age.

7 One can show that \( \kappa \left( \frac{p}{\mu} \right) \left( \frac{p}{\mu} \right)^2 \) is increasing in \( \frac{p}{\mu} \), so it is still true that a higher relative price of health increases the precautionary saving motive.
\[ s^* = \bar{s} + \left\{ \Omega^2 R[1 + \phi(\varepsilon - 2)] + \Omega(1 - \Omega)(2 - \epsilon_{c,h})(1 - \phi) \right\}(w + \bar{s}) \frac{\sigma \theta^2}{4\mu^2}, \]  

(18)

where \( \bar{s} = \frac{1}{2}\mu \chi_1 \), savings under certainty, \( \Omega \equiv h_2^*(p/\mu)/(w + \bar{s}) \), the share of income (full income plus capital income) spent on health \( h_2^* \) in the second period under certainty, and \( \epsilon_{c,h} \) is the elasticity of substitution between health and consumption goods.

Uncertainty surrounding medical care efficiency has two distinct effects on saving and medical expenditures. First, treatment uncertainty increases the riskiness of the rate of return on savings. This ‘capital risk’ effect is captured by the first term in brackets in Eq. (18). Whether this effect is positive or negative depends on risk and intertemporal smoothing preferences. If relative risk aversion is non-increasing, which implies \( \varepsilon \geq 1, \phi < 1 \) is sufficient for the capital risk effect to be positive. As shown by Selden (1979), under constant relative risk aversion a sufficient condition for capital risk to increase savings is \( \phi < 1 \).

Second, by changing the expected relative price of health, an increase in medical care risk also changes the expected return on savings. The ‘expected return’ effect is captured by the second term in brackets in Eq. (18). Whether the expected return effect is positive or negative depends on two factors. First, it is well known that an increase in the expected rate of return will decrease or increase savings depending on whether the elasticity of intertemporal substitution is smaller or larger than one. Second, it depends on whether an increase in uncertainty increases or decreases the expected rate of return. A sufficient condition for uncertainty to decrease the expected rate of return is that \( \epsilon_{c,h} \leq 2 \) (i.e. consumption and health are not very close substitutes).

We can therefore conclude,

**Proposition 2.** A sufficient condition for an increase in medical care risk to increase savings, decrease first period medical expenditures, and increase second period (expected) medical expenditures is that \( \varepsilon \geq 1 \), i.e. non-increasing relative risk aversion, \( \phi < 1 \), and \( \epsilon_{c,h} \leq 2 \). If relative risk aversion is non-decreasing (e.g. it is constant), \( \phi > 1 \), and \( \epsilon_{c,h} \leq 2 \), then, medical care risk decreases savings, increases first period medical expenditures, and decreases second period (expected) medical expenditures.

Equation (18), together with Proposition 2, demonstrate the importance of the distinction among ordinal preferences, attitudes towards risk, and attitudes towards intertemporal smoothing. Without information about each of these aspects of preferences one cannot determine the effect of medical care risk on savings and on medical care expenditures.
Health is unlikely to be a close substitute of consumption goods, so $\varepsilon_{c,h} < 2$ (see e.g. Viscusi and Evans, 1990; Finkelstein et al. 2008, 2009). Therefore, if one is willing to assume that individuals exhibit constant or decreasing relative risk aversion, it is the strength of preferences towards intertemporal substitution that determines the effect of medical care risk on savings and on medical care expenditures. Changes in the degree of risk aversion or in the elasticity of intra-temporal substitution may increase or decrease savings.

Although empirical estimates of $\phi$ tend to be lower than one, (e.g. Hall, 1988; Epstein and Zin, 1991) there is no consensus on the issue (e.g. Buffman and Leiderman, 1990; Attanasio and Weber, 1993). We should expect, in general, that policies that decrease the degree of uncertainty surrounding the effectiveness of medical care (e.g. stricter drug approval rules) will reduce the demand for savings and increase current medical expenditures for individuals that are highly averse to intertemporal fluctuations. For individuals who care relatively little about intertemporal smoothing, however, the opposite is likely to be true. For the knife-edge case of logarithmic intertemporal smoothing preferences ($\phi = 1$) changes in the degree of uncertainty will not change savings or medical expenditures.

This contrasts drastically from Dardanoni and Wagstaff (1990). They found, instead, that, given non-increasing relative risk aversion, medical care risk raises (lowers) medical expenditures if the price elasticity of medical care is lower (higher) than one [see also Koc (2004 a,b)]. As mentioned above, their framework is different to ours for two reasons: First, their model is static, so the saving decision is ignored. Second, in their model individuals select the level of medical care before the realization of shocks. To see the importance of endogenizing the saving decision, suppose that preferences are of the power/Cobb-Douglas form. In this case it is possible to find explicit solutions for savings and medical care expenditures that are independent of when the shocks are realized. Specifically, it is simple to show that

$$s^* = \frac{p}{\mu_1} x_1 + w \left[ 1 - \left( \frac{\mu_1}{\mu_2^{CE}} \right)^{b(1-\rho)\phi} \right] \left[ 1 + \left( \frac{\mu_1}{\mu_2^{CE}} \right)^{b(1-\rho)\phi} \right]^{-1}, \quad (19)$$

$$m_2^* = b \left[ \frac{w}{p} + \frac{x_1}{\mu_1} \right] \left[ 1 + \left( \frac{\mu_1}{\mu_2^{CE}} \right)^{b(1-\rho)\phi} \right]^{-1}, \quad (20)$$

where we have defined $\mu_2^{CE} \equiv \left[ E(\mu_2)^{b(1-\gamma)\frac{1}{b(1-\gamma)}} \right]^{b(1-\gamma)}$. $\mu_2^{CE}$ is the certainty equivalent of the second period effectiveness of medical care.

Given risk aversion, $\gamma > 0$, the certainty equivalent $\mu_2^{CE}$ is lower than the mean of $\mu_2$. Therefore, savings and second period medical expenditures (selected before or after the realization of the shock) increase with uncertainty if and only if
\( \rho > 1 \leftrightarrow \theta < 1 \), that is, if individuals are more averse to intertemporal fluctuations than those with logarithmic utility, precisely the same condition for lower treatment effectiveness to increase savings. Instead, in a framework in which the saving decision is exogenous medical care would be unresponsive to medical care risk (the price elasticity equals one in this case). 8

Japelli el al (2007) present evidence that consumers living in districts with lower quality of care save relatively more. As argued above, if consumers save more when treatment effectiveness is lower, they will also save more if variability of treatment effectiveness within a district is larger. This is a testable implication that Japelli et al do not consider. It is likely, however, that the interaction of quality of care and health risk which they do consider captures at least part of this relationship.

Although it is likely, as we have been assuming, that consumers can adjust the level of medical care once shocks are realized (e.g. if consumer falls ill) it is also likely that some investment in health capital can be made before the realization of the shocks (e.g. preventive care). In the next section we evaluate a model with those characteristics.

4. Uncertainty and Investments in Health Capital

We now investigate the possibility of investments in health capital. This differs from the previous framework in that health capital at the beginning of the second period is now determined endogenously. Specifically, in the first period the consumer can purchase an amount \( m^{prev} \) of preventive care at a price \( q \) per unit. Preventive care increases second period health, with a marginal effect of \( \mu^{prev} \).

We assume that \( \mu^{prev} = \bar{\mu}^{prev} + \xi_{\mu^{prev}} \) and \( \xi_{\mu^{prev}} \) is a mean zero random variable with variance \( \sigma_{\mu^{prev}}^2 \geq 0 \). The stochastic nature of \( \mu^{prev} \) can be interpreted both as a health risk (related to a preventable disease) and as treatment risk. For example, a low realization of \( \mu^{prev} \) may be interpreted as falling ill with influenza or with cervical cancer despite being vaccinated, as falling ill with diabetes despite investments in proper nutrition, or as having a dental ailment despite investments in oral health. Our consumer selects preventive care without knowledge of \( \mu^{prev} \), but knows its distribution.

To compare the results with those of the previous section we also consider a ‘pure’ health risk \( \xi_\chi \), a mean zero random variable with variance \( \sigma_\chi^2 \geq 0 \), which

8 More generally, in our framework, given \( \phi < 1 \) and non increasing relative risk aversion, an inelastic demand of medical care is sufficient (but not necessary) for medical care risk to increase savings. Specifically, one can write Eq. (18) as

\[
\hat{s}^* = \hat{s} + \left( \Omega^2 R[1 + \phi(\epsilon - 2)] + \Omega(2 - \epsilon_{m,p} - \Omega - \phi w + \sigma \mu^2 \mu^2) \right),
\]

where \( \epsilon_{m,p} \) is (minus) the price elasticity of medical care demand.
now reflects the possibility of unexpected and non-preventable diseases (e.g. bone fracture, leukemia). The health production functions are now given by

\begin{align}
    h_1 &= \chi_1 + \mu_1 m_1 \\
    h_2 &= \xi \chi_1 + \mu^{prev} m^{prev} + \mu_2 m_2.
\end{align}

(21)

The consumer maximizes lifetime utility by selecting the level of consumption goods and the level of medical care each period, and savings and preventive care in the first period, subject to the health production functions and the budget constraints,

\begin{align}
    c_1 + p m_1 + q m^{prev} &= w - s \\
    c_2 + p m_2 &= w + s.
\end{align}

(22)

We assume that the quality-adjusted prices of preventive care and medical care are the same under certainty, \( q/\mu^{prev} = p/\mu \). Furthermore, it simplifies the analysis to assume that utility exhibits constant relative risk aversion. Given these assumptions, in Appendix C we show that the demand for preventive care is

\begin{align}
    m^{prev} &= \frac{w+s}{q} \frac{\sigma_\mu^2}{R \sigma_\mu^2 + \sigma^{prev}_\mu}.
\end{align}

(23)

The demand for preventive care, as a share of second-period wealth, increases with medical care risk, it decreases with preventive care risk, with the degree of relative risk aversion, and with the cost per unit of preventive care, and it increases or decreases with the share \( \Omega \) according to \( R \gtrless 1 \). To better understand the determinants of the demand for preventive care note that we can rewrite Eq. (23) as

\begin{align}
    m^{prev} &= \left( \frac{\mu^{prev}}{q R} + \frac{\hat{\epsilon}_2}{\sigma_\mu^2 + \sigma^{prev}_\mu} \right) \sigma_\mu^2.
\end{align}

(23)

where \( \hat{\mu}^{prev} = \Omega (w + s) / q \) and \( \hat{\epsilon}_2 = (1 - \Omega) (w + s) \), the demand for preventive care and consumption goods that would be selected under certainty given a level of income \( w + s \) and no curative medical care. Therefore, the demand for preventive care has a health-consumption component and an investment component. Health is now produced with two inputs, preventive care

\[\text{Note: Our specification differs from the standard model of health capital in one respect. It is generally assumed that all purchases of health care at } t \text{ increase the health stock at time } t + i. \text{ In our model, the stock of initial health capital } \chi_1 \text{ is expected to depreciate completely (without loss of generality) but the consumer can 'buy' additional capital in the form of preventive care purchases. Medical care utilization when young does not affect the stock of health at a later age. For a related model of preventive and curative care see Hey and Patel (1983).}\]
and medical care, both of uncertain quality ex-ante. To consume the desired level of health the consumer uses a fraction \( \frac{\sigma_{\mu}^2}{\sigma_{\mu}^2 + \sigma_{\mu^{\text{prev}}}^2} \) of preventive care and a complementary fraction of medical care. The relative shares correspond to the degree of uncertainty over the quality of the two substitute inputs. In addition, for a given level of health, by investing in preventive care when young the consumer builds an asset that provides a rate of return \( (p\mu^{\text{prev}}/\mu_2) \) at a cost \( q \) per unit of investment. The consumer selects between this risky investment and the riskless financial asset with a zero rate of return. Each unit of the risky asset has an expected excess return that is proportional to \( \sigma_{\mu}^2 \) and a variance that is proportional to \( \sigma_{\mu}^2 + \sigma_{\mu^{\text{prev}}}^2 \). At an optimum the consumer buys \( \hat{c}_2/qR \) units of the risky asset.

Once the shocks are realized the consumer adjusts medical care to the level that maximizes utility ex-post, i.e. that attains a level of health \( g^h(p/\mu_2)z_2 \). Specifically, the second period demand for medical care is

\[
m_2^* = g^h \left( \frac{p}{\mu_2} \right) \frac{z_2 + s}{\mu_2} - \frac{\xi_x}{\mu_2} - \frac{\mu^{\text{prev}}m^{\text{prev}}}{\mu_2}.
\]

(24)

Therefore, for example, a low realization of \( \mu^{\text{prev}} \) (e.g. a new virus) implies that the (endogenous) level of health capital is also low, so the demand for medical care increases. Similarly, a low realization of \( \xi_x \) increases medical care.

Finally, in Appendix C we show that the saving rate is given by

\[
s^* = \bar{s} + \Lambda_x \frac{\sigma_x^2}{4} + \Lambda_{\mu^{\text{prev}}} (1 - \phi) \frac{\sigma_{\mu^{\text{prev}}}^2}{4} + \Lambda_{\mu} (1 - \phi) \frac{\sigma_{\mu}^2}{4},
\]

(25)

where \( \Lambda_x = R(1 + \phi) \left( \frac{p}{\mu} \right)^2 \), \( \Lambda_{\mu^{\text{prev}}} = R \left( \Omega_{\text{prev}} \right)^2 \left( \frac{w + s}{\mu^2} \right) \),

\[
\Lambda_{\mu} = R \left( \Omega - \Omega_{\text{prev}} \right)^2 + \Omega (1 - \Omega) \left( 2 - \epsilon_{c,h} \right) - 2 (1 - \Omega) \Omega_{\text{prev}} \left( \frac{w + s}{\mu^2} \right),
\]

with \( \Omega_{\text{prev}} = \frac{q\mu^{\text{prev}}}{w + s} \) (i.e. preventive care expenditures as a proportion of second period income).

In addition to saving \( \bar{s} \) for the expected depreciation of the initial health capital that occurs with age, the consumer adjusts the level of savings to account for the multiple sources of uncertainty. As in Section 3.1, health risk is equivalent to income uncertainty, increasing precautionary saving given DARA (e.g. CRRA). The demand for saving reflects four additional effects of uncertainty on the (endogenous) rate of return. The term \( \Lambda_{\mu^{\text{prev}}} \) and the first term in brackets in \( \Lambda_{\mu} \) reflect the increase in the riskiness of the rate of return on savings due to uncertainty about preventive care and medical care effectiveness. As argued above, \( \phi < 1 \) is sufficient for the capital risk effect to be positive under CRRA.
The other two effects represent changes in the expected rate of return. The second term in brackets in $\Lambda_\mu$ is the same as that we encountered in Eq. (18), i.e. a decrease in the expected return given $2 > \epsilon_{c,h}$. The third term in brackets in $\Lambda_\mu$ represents the increase in the expected excess return of health capital that occurs when medical care effectiveness becomes more uncertain, decreasing savings if $\phi < 1$. Importantly, if $\phi = 1$, uncertainty surrounding the effectiveness of medical care and of preventive care does not affect saving at all.

Two special important cases are worth noting. First, if $\sigma_{\mu,prev}^2$ is much higher than $\sigma_{\mu}^2$ the demand for preventive care will be close to zero, so $\Omega_{prev} \approx 0$, and the saving rate will be approximately equal to the cases analyzed in sections 3.1 and 3.2 [Equations (14) and (17)]. Given constant relative risk aversion, $2 > \epsilon_{c,h}$, and $\phi < 1$ savings increase with the degree of uncertainty surrounding the quality of medical care.

Second, if $\sigma_{\mu,prev}^2 \approx 0$ one can show that savings equal

$$s \approx \bar{s} + \Lambda_\chi \frac{\sigma_{\chi}^2}{4} \left[1 - \phi(1 - \Omega)[1 - \Omega(1 - \epsilon_{c,h}R)]\right] \frac{\sigma_{\mu}^2}{R \mu^2}.$$

which leads to

**Proposition 3.** Given an optimally selected level of preventive care, if $\sigma_{\mu,prev}^2 = 0$ and $\phi < 1$, then, an increase in the degree of uncertainty surrounding medical care effectiveness decreases saving.

Intuitively, when preventive care effectiveness is certain consumers can (better) self-insure against future medical care risk by buying preventive care at a younger age. Given this insurance, the consumer expects to purchase medical care only if it is highly efficient and or if she falls ill with a non-preventable disease. As a result, the expected rate of return on savings increases and its riskiness decreases. The expected return effect now overcomes the capital risk effect, so savings decrease with medical care uncertainty if $\phi < 1$. The risk of falling ill with a non-preventable disease cannot be hedged, so the consumer still saves an extra amount $\Lambda_\chi (\sigma_{\chi}^2/4)$ as a precaution.

### 4.1. Medical Care Risk and Welfare

The fact that preventive care acts as a hedging mechanism, together with the possibility of adjusting the level of medical care once shocks are realized, raises the following question: can consumers gain from variability in health care effectiveness? The following proposition, which we prove in Appendix C,
establishes the conditions for uncertainty surrounding the quality of health care to increase consumers’ welfare.

**Proposition 4.** Uncertainty surrounding health care effectiveness increases expected utility if

\[ \Lambda \mu \sigma_{\mu}^2 + \Lambda \sigma_{\mu}^2 < 0. \] (26)

If \( \sigma_{\mu}^2 = 0 \), uncertainty surrounding medical care effectiveness unambiguously increases welfare.

In essence, if savings decrease with uncertainty when \( \phi < 1 \), welfare increases with uncertainty. Since most empirical estimates of \( \phi \) tend to be lower than one, this is a highly plausible scenario.

At first glance, it is surprising that consumers may gain from variability in health care effectiveness. There is, however, a simple intuition. Eaton (1980) showed that if consumers can hedge price uncertainty by purchasing a good in advance, then, they will unambiguously gain from more variability. Intuitively, consider a consumer that finds it optimal to purchase the bundle \((x_0, y_0)\) when the relative price of good \(y\) is \(p_0\). Suppose now that the consumer faces uncertainty on the relative price but he or she can purchase some amount of good \(y\) before the realization of uncertainty at a price \(p_0\). Suppose that he or she purchases an amount \(y_0\) in advance. Then, the consumer can never be worse off by the introduction of uncertainty (or by more variability). If the price is equal or higher than \(p_0\) the consumer can always attain the same utility as in the case without uncertainty by consuming the bundle \((x_0, y_0)\). If, on the other hand, the price turns out to be lower, he or she can consume a bundle that provides higher utility.

Essentially the same intuition holds for uncertainty about medical care effectiveness when the consumer can invest in health by purchasing preventive care (recall that the relative price of health is \(p/\mu\)). A larger variability of medical care effectiveness means that consumers are more likely to encounter very efficient (and very inefficient) treatments in the future. If, in addition, investments in health capital are relatively safe, the consumer expects to benefit from these high realizations of medical treatment effectiveness while maintaining a good level of health if treatment effectiveness is low.
5. Conclusions

As suggested by Dardanoni and Wagstaff (1990), one can interpret the degree of uncertainty surrounding health care expenditures as the consumers’ lack of information to accurately diagnose their health state and to understand the effectiveness of different treatments and also as the intrinsic uncertainty that consumers face due to the stochastic nature of their health and the efficacy of treatments. Policies that change the degree of uncertainty that consumers face (e.g. health awareness campaigns, stricter drug approval rules, incentives for the creation and adoption of new drugs and technologies) will affect their demand for health care over the life cycle as well as their saving behavior and their welfare. In this paper we analyzed precisely these effects.

We extended Dardanoni and Wagstaff (1990) because it constitutes the canonical model of the demand for medical expenditures under uncertainty. Our purpose in doing so is best summarized in the evocative phrase of Campbell (1994), although he obviously used it in a very different context: by focusing on the most stripped down version of the problem we can “inspect the mechanism,” revealing exactly how uncertainty interacts with different aspects of preferences in order to affect behavior. The insights provided by this theoretical exercise should guide the formulation and calibration of simulation studies, epitomized by Hubbard et al (1995). The theoretical skeleton could also be fleshed out to yield empirical insights on additional policy issues. It should be possible to add endogenous health insurance, for example, or to incorporate important institutional details such as the fact that some consumers are unable to acquire insurance.

We showed that consumers save an extra amount when faced with uncertainty surrounding the incidence of illness (in the empirically plausible case of DARA). In essence, conditional on the optimal demand of consumption goods and medical care, health uncertainty is equivalent to income uncertainty, which is the implicit assumption in most empirical papers that look for a link between uncertainty surrounding health care expenditures and saving behavior.

The conditions for precautionary saving when the effectiveness of medical care is uncertain, however, are more complex. If savings increase, consumers reduce the demand for medical (curative) care when young. However, in the presence of uncertainty surrounding medical treatments of preventable diseases (e.g. diabetes, cervical cancer, influenza, hepatitis), consumers purchase additional (preventive) care when young as a form of self-insurance. Given this insurance, consumer’s welfare may increase with the degree of uncertainty over medical care effectiveness.

We also showed that the separation of ordinal preferences from risk and intertemporal smoothing attitudes is central for understanding how uncertainty
affects health care demand and the accumulation of wealth. For example, in the case of uncertainty surrounding the incidence of illness the degree of risk aversion increases the precautionary strength but the degree of aversion to intertemporal fluctuations decreases the precautionary strength. Given uncertainty surrounding the effectiveness of medical care, information about the three aspects of preferences is necessary to understand the consumer’s precautionary motives. Under plausible assumptions, whether uncertainty surrounding the effectiveness of medical care increases or decreases savings is determined entirely by the degree of aversion to intertemporal fluctuations; consumers that are more risk averse may save less. In the more likely case that the elasticity of intertemporal substitution is lower than one, uncertainty surrounding the effectiveness of treatments of non-preventable (preventable) diseases will increase (decrease) savings.

These results have important policy implications. Consider, for example, the regulation of medical treatments and medical technology. In the United States the U.S. Food and Drug Administration (FDA) is responsible for, broadly speaking, ‘assuring the efficiency and safety of new drugs, vaccines and other biologics, and medical devices.’ Strict drug approval regulations have been criticized for slowing down the innovative process and for reducing the incentive to innovate (e.g. Gieringer 1985). On the other hand, FDA regulations are likely to improve the expected quality of treatments and technologies. By increasing ‘safety’, it is also likely that FDA regulations decrease the degree of uncertainty surrounding the quality of treatments and technologies. As a result, the trade-off has generally been perceived as one between lower availability and enhanced effectiveness and safety.

Our results indicate that stricter FDA regulations will also affect wealth accumulation as well as expenditures on curative care and preventive care. In particular, rules that decrease the degree of uncertainty surrounding the effectiveness of treatments of non-preventable (preventable) diseases will decrease (increase) savings and increase (decrease) current expenditures in curative care. These rules should also lead to lower expenditures in preventive care as a proportion of wealth.

More strikingly, our results suggest that such regulations may reduce consumer’s welfare, precisely because they reduce the degree of uncertainty regarding the quality of treatments and technologies. In other words, less strict regulation implies that consumers will face highly effective treatments that would otherwise be unavailable (and very ineffective treatments). If preventive care is relatively safe, young consumers will invest larger amounts in prevention and,

---

10 The fact that uncertainty surrounding the effectiveness of treatments of non-preventable and of preventable diseases may have opposing effects on the accumulation of wealth highlights the importance of understanding how policies affect different types of diseases.
given this insurance, will gain from less strict regulation in the market for curative care products. More generally, our results suggest that the debate on the stringency of FDA regulations should include a trade-off that has previously not been considered between the efficacy of treatments and the availability of treatments with different (or more variable) degrees of efficiency.

A specific example is the treatment for the HIV virus. Although some treatments for the HIV virus have been discovered (and some approved by the FDA), their effectiveness is highly uncertain, especially given the rapid mutation of the virus and its ability to develop resistance to drugs.\(^{11}\) Our analysis suggests that the existence of drugs with more variable treatment effectiveness, together with safe prevention mechanisms (e.g. condoms), may increase consumer’s welfare (of course, a treatment with higher effectiveness would also be preferable).

The HIV virus case is also a good example of two other more general phenomena. First, the emergence and the diffusion of innovations in the medical industry are highly uncertain processes. Policies that increase the degree of uncertainty surrounding these processes may increase consumer’s welfare. Second, multiple treatment options with different degrees of effectiveness may co-exist and consumers may benefit from having these multiple options.

### Appendices

#### Appendix A. Precautionary Saving with Health Risk

Our analysis of the effects of health risk is based upon the methods used by Kimball and Weil (2009) and Nocetti and Smith (2010). Recall that the first order condition for savings is

\[
u'[(\kappa(z_1 - s)] = u'[M(s)]M'(s), \quad (A.1)\]

where \(\kappa = \kappa \left( \frac{p}{\mu} \right), \quad z_1 = w + \chi_1 \frac{p}{\mu}, \) and \(M(s) = \nu^{-1}\{E\nu[\kappa(z_2 + s)]\}\) with \(z_2 = (w + \chi_2 \frac{p}{\mu}).\)

Now – à la Pratt (1964) – take a Taylor series of \(M(s)\) around \(\xi_x = 0\) to find

\[
M(s) = \kappa(\bar{z}_2 + s) - A[\kappa(\bar{z}_2 + s)]\kappa^2 \frac{\sigma_x^2}{2} + o(\sigma_x^2), \quad (A.2)
\]

where $o(\sigma^2)$ collects terms that go to zero faster than $\sigma^2$. It follows that

$$ M(s)' = \kappa - A'[\kappa(z_2 + s)]\kappa^2 \frac{\sigma^2}{2} + o(\sigma^2). \tag{A.3} $$

Substitute Equations (A.2) and (A.3) back into Eq. (A.1). Disregarding the $o(\sigma^2)$ terms, this yields

$$ u'[\kappa(z_1 - s)]\kappa = u'[\kappa(z_2 + s) - A[\kappa(z_2 + s)] \left(\frac{\kappa\mu}{\mu}\right)^2 \frac{\sigma^2}{2} \right][\kappa - \frac{A'[\kappa(z_2 + s)]\kappa}{\kappa(z_2 + s)} \left(\frac{\kappa\mu}{\mu}\right)^2 \frac{\sigma^2}{2}]. \tag{A.4} $$

Recall that the optimal expenditure profile is flat in the absence of uncertainty, so that $z_1 - s = z_2 + s = Z$. Using this fact, take a Taylor series of Eq. (A.4) around $s = \bar{s}$ and $\sigma^2 = 0$,

$$ u'/(\kappa Z)\kappa - u'/(\kappa Z)\kappa^2(s - \bar{s}) = u'/(\kappa Z)\kappa + u'/(\kappa Z)\kappa^2(s - \bar{s}) - \{u'/(\kappa Z)A[\kappa Z]\kappa + u'/(\kappa Z)A'[\kappa Z]\kappa\} \left(\frac{\mu}{\mu}\right)^2 \frac{\sigma^2}{2}. \tag{A.5} $$

Simplifying gives

$$ s - \bar{s} = \left\{A[\kappa Z] + \frac{u'/(\kappa Z)}{u'/(\kappa Z)A'[\kappa Z]}\right\} \left(\frac{\mu}{\mu}\right)^2 \frac{\sigma^2}{4}. \tag{A.6} $$

Since $f = \kappa Z$, $R = Af$, $\epsilon = -A'f/A$, and $\phi = -u'/u''f$ we obtain

$$ s - \bar{s} = R\left\{1 + \phi\epsilon\right\} \frac{1}{Z} \left(\frac{\mu}{\mu}\right)^2 \frac{\sigma^2}{4}. \tag{A.7} $$

which is Eq. (19) in the text.

**Appendix B. Precautionary Saving with Medical Care Risk**

In this case certainty equivalent utility is

$$ M(s) = \kappa(z_2 + s) - \left[A\kappa(z_2 + s) - \kappa\mu\mu\right](z_2 + s) \frac{\sigma^2}{2} + o(\sigma^2), \tag{A.8} $$
where $\kappa = \kappa \left( \frac{p}{\mu} \right)$, $z_2 = w$, and $A$ is evaluated at $z_2 + s$. It follows from Eq. (A.8) that

$$M'(s) = \kappa - \left[ A' \kappa \mu^2 (z_2 + s)^2 + 2A \kappa \mu^2 (z_2 + s) - \kappa \mu \right] \frac{\sigma^2}{2} + O(\sigma^2). \quad (A.9)$$

Substitute Equations (A.8) and (A.9) back into the first-order condition to find

$$u'[\kappa Z] \kappa = u'[\kappa Z] - \left[ A' \kappa \mu^2 Z - \kappa \mu \mu \right] Z \frac{\sigma^2}{2} \left[ \kappa - \left[ A' \kappa \mu^2 Z^2 + 2A \kappa \mu^2 Z - \kappa \mu \mu \right] \frac{\sigma^2}{2} \right]. \quad (A.10)$$

Here we have normalized $\mu_1 = \bar{\mu}_2 = \mu$, suppressed the lower-order terms, and used the fact that in the absence of uncertainty $z_1 - s = \bar{z}_2 + s = Z$. Taking a Taylor series expansion of Eq. (A.10) around $\sigma^2 = 0$ and $s = \bar{s}$ gives

$$u'(\kappa Z) \kappa - u'/(\kappa Z) \kappa^2 (s - \bar{s}) = u'(\kappa Z) \kappa + u'/(\kappa Z) \kappa^2 (s - \bar{s}) - \left[ u'/(\kappa Z) \kappa \left[ A \kappa \mu^2 Z - \kappa \mu \mu \right] Z - u'(\kappa Z) \left[ A' \kappa \mu^2 Z^2 + 2A \kappa \mu^2 Z - \kappa \mu \mu \right] \frac{\sigma^2}{2} \right]. \quad (A.11)$$

This simplifies to

$$s - \bar{s} = \left\{ A \kappa (\kappa \mu Z / \kappa)^2 (1 + \phi(\varepsilon - 2)) - (\kappa \mu \mu Z / \kappa)(1 - \phi) \right\} \left( \frac{\sigma^2}{2} \right), \quad (A.12)$$

where $\bar{s} = \frac{1}{2} \frac{p}{\mu} \chi_1$.

To interpret (A.12) notice that Roy’s identity implies that under certainty $h_2^* = \kappa \mu^2 (w + \bar{s}) / k \rho$, which in turn implies that $\kappa \mu \mu / \kappa = h_2^* (p / \mu) / (w + \bar{s})$. We will define $\Omega = h_2^* (p / \mu) / (w + \bar{s})$, the share of income (full income plus capital income) spent on health in the second period. One can also show that $\kappa \mu \mu / \kappa = -\Omega(1 - \Omega)(2 - \varepsilon_{c,h})$, where $\varepsilon_{c,h}$ is the elasticity of substitution between health and consumption goods. Using these relationships we can re-write (A.12) as

$$s^* = \bar{s} + \left\{ \Omega^2 R[1 + \phi(\varepsilon - 2)] + \Omega(1 - \Omega)(2 - \varepsilon_{c,h})(1 - \phi) \right\} (w + \bar{s}) \frac{\sigma^2}{4 \mu \rho^2}. \quad (A.12')$$

which is Eq. 18 in the text.
Appendix C. Proof of Results in Section 4

To derive the optimal level of the choice variables we proceed in three steps.

1. Select the optimal level of medical care given savings and preventive care.

This gives

\[ m_1^* = g^h \left( \frac{p}{\mu_1} \right) \frac{z_1 - s}{\mu_1} - \frac{\chi_1}{\mu_1} \quad \text{and} \quad m_2^* = g^h \left( \frac{p}{\mu_2} \right) \frac{z_2 + s}{\mu_2} - \frac{\xi \mu_{\text{prev}}}{\mu_2}, \]  

(A.13)

and the indirect lifetime utility function is

\[ u \left[ \kappa \left( \frac{p}{\mu_1} \right) \left( w - s + \chi \left( \frac{p}{\mu_1} \right) \right) \right] + u[M(.)], \]  

(A.14)

where

\[ M(.) = \nu^{-1} \left[ Ev \left[ \kappa \left( \frac{p}{\mu_2} \right) \left( w + s + \frac{p\chi}{\mu_2} + m_{\text{prev}} \left( \frac{(p\mu_{\text{prev}})}{\mu_2} - q \right) \right) \right] \right]. \]

2. Select the optimal level of preventive care to maximize second period utility given savings.

A Taylor series approximation around \( \xi \chi = 0 \), \( \xi \mu = 0 \), \( \xi \mu_{\text{prev}} = 0 \), \( \sigma_{\mu}^2 = 0 \), \( \sigma_{\mu_{\text{prev}}}^2 = 0 \), and \( \sigma_{\chi}^2 = 0 \), and recalling our assumption that \( p/\mu = q/\mu_{\text{prev}} \), reveals that second period utility can be approximated as

\[ u[.] - u^\prime[.] \left\{ G_{\mu} \frac{\sigma_{\mu}^2}{2} + G_{\mu_{\text{prev}}} \frac{\sigma_{\mu_{\text{prev}}}^2}{2} + G_{\chi} \frac{\sigma_{\chi}^2}{2} \right\}. \]  

(A.15)

with

\[ G_{\mu} = A \left( \kappa_{\mu} (w + s) - \frac{km_{\text{prev}}q}{\mu} \right)^2 - \kappa_{\mu\mu} (w + s) + \frac{2m_{\text{prev}}q}{\mu^2} (\kappa_{\mu\mu} - \kappa), \]

\[ G_{\mu_{\text{prev}}} = A \left( \frac{km_{\text{prev}}q}{\mu} \right)^2, \]

\[ G_{\chi} = A \left( \frac{p}{\mu} \right)^2. \]
Maximizing Eq (A.15) with respect to $m_{\text{prev}}$ and simplifying gives
\[
\left[-A \left(\frac{\kappa}{\mu}\right) (\Omega(w + s) - m_{\text{prev}}q) - \frac{1-\Omega}{\mu} \sigma^2_{\mu} + Am_{\text{prev}} \left(\frac{\kappa q}{\mu}\right) \frac{\sigma^2_{\text{prev}}}{2}\right] = 0. \tag{A.16}
\]

Therefore,
\[
m_{\text{prev}} = \left[\frac{\Omega(w + s)}{q} + \frac{1-\Omega}{Akq} \frac{\sigma^2_{\mu}}{\sigma^2_{\mu} + \sigma^2_{\text{prev}}}\right], \tag{A.17}
\]

which can be written as
\[
m_{\text{prev}} = \frac{(w + s)(1-\Omega(1-R))}{q} \frac{\sigma^2_{\mu}}{R \sigma^2_{\mu} + \sigma^2_{\text{prev}}}. \tag{A.18}
\]

3. Select the optimal level of savings

Plugging the optimal level of preventive care back into the indirect utility function
\[
u[\kappa(w - s + \chi(p/\mu))] + u \left[v^{-1} \left[ E\left[(w + s)r(\mu_{\text{prev}}, \mu_2) + \kappa \left(\frac{p}{\mu_2}\right) \xi_{\chi} \frac{p}{\mu_2}\right]\right]\right]. \tag{A.19}
\]

where $r(\mu_{\text{prev}}, \mu_2) = \kappa \left(\frac{p}{\mu_2}\right) \left[1 - \left(1 - \frac{\mu_{\text{prev}}}{\mu_2}\right) \frac{(1-\Omega(1-R))}{R \sigma^2_{\mu} + \sigma^2_{\text{prev}}}\right]$. Note that $r(\bar{\mu}_{\text{prev}}, \bar{\mu}_2) = \kappa$. It should be clear that the effect of the mean zero risk $\xi_{\chi}$ on savings is the same as that provided in part A of the Appendix, so we will continue by setting $\xi_{\chi} = 0$.

An approximation of the first order condition around $\xi_{\mu} = 0$, $\sigma^2_{\mu} = 0$, $\sigma^2_{\text{prev}} = 0$ and $s = \bar{s}$ and using the assumption of constant relative risk aversion gives
\[
s = \bar{s} + \left[(r_1(w + \bar{s}))^2 - r_{11}\right] (1 - \phi) \frac{A \sigma^2_{\text{prev}}}{\kappa} + \left[(r_2(w + \bar{s}))^2 - r_{22}\right] (1 - \phi) \frac{A \sigma^2_{\bar{\mu}}}{\kappa}. \tag{A.20}
\]

where $r_i$ is the derivative of $r(\mu_{\text{prev}}, \mu_2)$ with respect to its $i$th argument evaluated at $\bar{\mu}_{\text{prev}}$ and $\bar{\mu}_2$.  

Published by The Berkeley Electronic Press, 2010
Taking the appropriate derivatives gives Eq. (25) in the text. This finishes the proof of Proposition 3.

Plugging Equation (A.17) back into (A.15) one obtains condition Eq. (26) in the text. When \( \sigma_{\mu, prev}^2 = 0 \) one can write this condition as

\[
\left\{ 1 - \Omega (1 - \epsilon_{h,c} R) \right\} \frac{\sigma_{\mu}^2}{2} > 0.
\]

(A.21)

Since \( \left\{ 1 - \Omega (1 - \epsilon_{h,c} R) \right\} > 0 \), medical care risk increases welfare, which finishes the proof of Proposition 4.

References


http://www.bepress.com/bejeap/vol10/iss1/art75
