

Helping Patients and Physicians Reach Individualized Medical Decisions: Theory and Application to Prenatal Diagnostic Testing

By

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Abstract

This paper presents a procedure designed to aid physicians and patients in the process of making medical decisions, and illustrates its implementation to aid pregnant women, who decided to undergo prenatal diagnostic test choose a physician to administer it. The procedure is based on a medical decision making model of Karni (2009). This model accommodates the possibility that the decision maker's risk attitudes may vary with her state of health and incorporates other costs, such as pain and inconvenience, associated with alternative treatments. The medical decision problem was chosen for its relative simplicity and the transparency it affords.

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1 Introduction

Consider the following scenario: A patient diagnosed with a health problem must choose among alternative courses of action, including a treatment, a physician to administer it, and a medical facility in which the treatment is to be administered. In general, the alternatives to be considered are quite complex, involving assessment of risks and values, as well as financial and lifestyle considerations, and difficult to assess as wholes. There is an advantage, therefore, in breaking them up so that the different components may be evaluated separately, and then aggregating these evaluations to generate a decision criterion. This process necessitates inputs from both doctor and patient. Typically the doctor's input includes specifying the alternative treatments, describing the possible medical outcomes, and providing an assessment of the risks involved in each treatment at different facilities and by different physicians. The patient's input includes his/her personal valuation of the potential medical outcomes as well as his/her financial and other concerns, such as its impact on his/her lifestyle and family.² In principle, if there is no conflict of interests between doctor and patient, integrating these inputs should enable the patient to choose his optimal course of action. In practice, however, it is not always easy to obtain the necessary information from the doctor or to elicit the patient's preferences. Both may require some guidance on how to sort out and organizing the relevant information in a systematic manner, and identify the optimal course of action.³

Karni (2009) presented an axiomatic model of medical decision making in which the various ingredients of the decision making process described above and the aggregation procedure are made explicit. The procedure requires the elicitation and integration of the patient's preferences and the physician's risk assessment.

In this study we show how to apply this model to help doctors and patients arrive at a decision that best serves the patients' interests. More specifically, we formulated questionnaires designed to prompt patients to reveal their evaluation of the medical

²For a more detailed description of the shared decision-making model in medical context, see Charles et. al. (1977, 1999a, 1999b) and Lewis, et. al. (2005).

³See discussion in Kremer et. al. (2007), Hudak et. al. (2008) and Holmes Rover et. al. (2007).

outcomes and financial consequences of the alternative courses of actions. We review the results to see if the responses are consistent with the basic premises on the model, and illustrate, using a few case studies, how it generates recommendations regarding which course of action should be followed.

Our approach is normative but not paternalistic. It is normative in its presumption that the patient would like his decision to be governed by the principles (axioms) of expected utility theory, which we take as normatively compelling. It is non-paternalistic in that the recommended course of action maximizes the patient's expected utility, but is silent on what this utility should be. The patient is the ultimate arbiter of his own well-being.

The application of the model presumes that, when properly prompted to do so, patients are able to express their preferences in a coherent manner. This study, is intended to tests this presumption. Specifically, we consider pregnant women who decided to undergo prenatal diagnostic test, which is not recommended for routine pregnancy, to determine genetic abnormalities. The test involves a risk of involuntary abortion, and has the benefit of allowing voluntary early termination of the pregnancy if genetic abnormalities are detected. The risk of involuntary abortion depends, among others, on the expertise and skill of the physician administering the test. Upon being informed of the alternative courses of action, the woman must choose the physician to administer the test.

It is not uncommon that, facing such decision, the woman will ask her gynecologist (who does not necessarily perform diagnostic tests) for recommendation. Confronted with such requests, the gynecologist may find himself in a difficult position. Presumably, his answer should depend on the assessment of the risk involved, the woman's valuation of the potential outcomes which depends on her age, family situation (how many children she has, etc.). Finally, the answer must take into account financial considerations, such as the price differences among physicians and medical facilities, the women's risk attitudes which may depend, in turn, on the outcome of the diagnostic test and her wealth.

The main difficulty is the elicitation of the patient's preferences. These involves

the patient's risk attitudes, which may vary according to the outcome, the alignment of her utility functions across outcomes, and the calibrations of the utility functions across courses of actions. To reduce the problem to manageable size, for the purpose of this study, we invoke a family of utility functions characterized by one parameter, which may vary according to the outcome of the medical procedure. This permits the patient's risk attitude to depend on her health-state. We develop a questionnaire that makes it possible to elicit the values of the said parameter conditional on the alternative outcomes and the alignment of the utility functions. Using this information we illustrate the application of the model to help patients and gynecologists arrive at a decision consistent with the information at their possession. We also use the responses to check whether they are consistent with basic premises of rational choice behavior.

The decision problem we study is rather simple and transparent, namely, the choice of physician to administer a prenatal diagnostic test. The term prenatal diagnosis refers broadly to a number of different techniques and procedures that can be performed during a pregnancy to provide information about the health of a developing fetus. Prenatal diagnostic tests may also be offered to women whose pregnancies are considered high risk because of age, family history, or other factors. These tests are designed to look for specific conditions, but not all conditions can be detected and no test is completely accurate.⁴ In this study we consider the two commonly used tests described below:

Chronic Villus Sampling (CVS) - is usually performed between 10 and 13 weeks of gestation and is designed to detect specific genetic abnormalities early in pregnancy. The greatest success occurs when the physician performing the test is experienced CVS can be used to determine virtually all disorders that can be diagnosed by amniocentesis except the presence of neural tube defects.

Amniocentesis - is usually performed between 15 and 20 weeks of gestation, to detect chromosomal abnormalities as well as other specific genetic diseases. The

⁴For details regarding this point and information concerning the procedures described below, see the Genetics and Public Policy Center on the web site www.dnapolicy.org.

results from amniocentesis are highly accurate.

Amniocentesis is a relatively simple and safe procedure when performed by an experienced physician, but there is some risk for miscarriage. That risk has been quoted at being about 1 in 200. However, recent data suggests that in experienced hands, the risk may be much lower.

CVS carries a slightly higher increased risk of miscarriage (still less than one percent) than amniocentesis. In both procedures, the rate of pregnancy loss is lower when performed by experienced physician and in medical center where the procedures are performed more often. Moreover, evidence suggest that experience of the physician is relatively more important for reduce rate of miscarriage in CVS than in amniocentesis.

2 The Medical Decision Model: A Review

In this section we review the model proposed by Karni (2009), describe the parametric family of utility functions used in our study, and the procedures invoked to determine the patients' objective functions.

2.1 The analytical framework

Assume that patients' preferences are represented by action and outcome-dependent expected utility function. Formally, let A denote the set of available courses of action, or treatments, and denote by c a vector of the patient's characteristics (medical history, age, gender, race, profession, family situation, physical state, and any other personal attributes that may bear on the outcome of the medical treatments under consideration). Let the patient preference relation \succsim on A be represented as follows:

$$(a, c) \mapsto \lambda(a) \sum_{\omega \in \Omega} [b(\omega) U(f(\omega; a, c), \omega) + d(\omega)] p(\omega | a, c) + v(a), \quad (1)$$

where U is the utility function; ω denotes the post-treatment health state (or outcome); Ω is the set of all outcomes associated with a given diagnosis; $f(\omega; a, c)$ denotes the financial consequence associated with the outcome ω conditional on the patient's characteristics and the action; $p(\cdot | a, c)$ is the probability distribution on Ω condi-

tional on the action and the patient's personal characteristics; and λ and v represent the "utility cost," including pain, discomfort and inconvenience associated with different actions⁵. Note that the patient's risk attitudes, captured by the utility functions of money, $U(\cdot, \omega)$, $\omega \in \Omega$, are outcome dependent but not action dependent.⁶

In the context of this model, decisions are based on information from two sources: (a) medical information, provided by the doctor, specifying the possible courses of action, A , the potential outcomes, Ω , and the family, $\{p(\cdot, a, c) \mid a \in A\}$, of probabilities on Ω conditional on the actions and patient's characteristics, and (b) personal information, provided by the patient, concerning his characteristics and preferences. Using this information, the relevant utility functions U , λ and v are determined.

The elicitation of the subjective "parameters" (that is, the outcome-dependent utility functions and action-dependent "utility cost" coefficients) involves three distinct procedures. First, for every given outcome, it is necessary to elicit the outcome-dependent utility function on wealth (that is, for all $\omega \in \Omega$, the functions $U(\cdot, \omega)$ must be determined). Second, the outcome-dependent utility functions need to be aligned, so that they agree on the evaluation of the monetary payoff across outcomes (that is, the coefficients $b(\omega)$ and $d(\omega)$, $\omega \in \Omega$, need to be determined). Third, the expected utilities of the distinct actions must be calibrated to allow comparisons among them (that is, the coefficients $\lambda(a)$ and $v(a)$, $a \in A$ need to be determined).

In the next subsection, we review these procedures as applied to our problem. Before doing so, however, it is worth mentioning again the possible interpretations of the model. One possible interpretation is positive. According to this interpretation the patient has a preference relation representable as in (1). Upon learning the information provided by his doctor, the patient should be able to choose the course of action appropriate from him. For some patients this is the case.

Another possible interpretation is normative. According to this interpretation,

⁵The fact that in general the utility cost associated with a procedure has additive and multiplicative factors is a consequence of the axiomatic structure of the underlying preference relation. It is quit possible that in application it will turn out that the estimated value of λ is one.

⁶Outcomes represent states of health, and the utility functions in this model are state-dependent functions of the patient's wealth.

some patients would have liked to choose according to the principles underlying the preference relation represented in (1), but are unable to do so intuitively. Such patients need guidance to help them clarify, in their own minds, their preferences and, following that, to aid them identify the course of action recommended by the model.

The present study assumes the normative interpretation and our main concern is developing the means to guide patients of the second kind through their decision making process.

2.2 Elicitation of patients' risk attitudes

As a compromise between rigor and parsimony, we restrict attention to parametric families of utility functions and estimate the relevant parameters using few questions. More specifically, we employ a one-parameter expo-power utility function of the form,

$$u(x, \omega) = -e^{\frac{-x^{r(\omega)}}{r(\omega)}}, \text{ for } r(\omega) \neq 0 \text{ and } u(x, \omega) = -1/x \text{ for } r(\omega) = 0, \quad (2)$$

where x denotes the patient's wealth and $1 \geq r(\omega) \geq 0$, $\omega \in \Omega$.⁷ For $r(\omega) \in (0, 1]$, this function displays decreasing absolute and increasing relative risk aversion.⁸

To determine the risk attitudes of the women in this study, we elicit their certainty equivalents of small risks. Specifically, let x denote the subject's wealth and let $\tilde{\varepsilon}$ be a random variable taking values in the interval $(-\varepsilon, \varepsilon)$ such that $E(\tilde{\varepsilon}) = 0$, where E denotes the expectations operator. For each x and ω let $\pi(x, \omega)$, the relative risk premium, be defined by the equation

$$u(x - \pi(x, \omega)x, \omega) = E[u(x + \tilde{\varepsilon}x, \omega)]. \quad (3)$$

In other words, $\pi(\cdot, \omega)$ is the (maximal) proportion of her wealth a subject is willing

⁷The expo-power family of utility function was first proposed by Saha (1993). The one parameter variation invoked in this study was used in Abdellaoui et al. (2007). The two parameter variation

$$u(x) = \frac{1 - \exp(-\alpha x^{1-r})}{\alpha},$$

where x denotes the decision maker's wealth; $\alpha > 0$ and $1 \geq r \geq 0$, was used by Holt and Laury (2002).

⁸Note that $-\frac{u''(x, \omega)}{u'(x, \omega)} = x^{-(1-r(\omega))} + (1-r(\omega))x^{-1}$.

to pay to avoid the proportional risk $\tilde{\varepsilon}$. For small risks we have, for each ω ,

$$\pi(x, \omega) = \left[-\frac{u''(x, \omega)x}{u'(x, \omega)} \right] \frac{\sigma_{\tilde{\varepsilon}}^2}{2}. \quad (4)$$

In the one-parameter expo-power utility function the Arrow-Pratt measure of relative risk aversion is:

$$-\frac{u''(x, \omega)x}{u'(x, \omega)} = x^{r(\omega)} + 1 - r(\omega). \quad (5)$$

Hence, given $x, \tilde{\varepsilon}$ and $\pi(x, \omega)$, we can solve for $r(\omega)$, $\omega \in \Omega$, using the equations

$$\pi(x, \omega) = [x^{r(\omega)} + 1 - r(\omega)] \frac{\sigma_{\tilde{\varepsilon}}^2}{2}, \omega \in \Omega. \quad (6)$$

2.3 Alignment of the utility functions

Recall that, in the case under consideration, there are two outcomes, continued pregnancy without complications ω_0 , and involuntary abortion, ω_1 (that is, $\Omega = \{\omega_0, \omega_1\}$)⁹. Suppose that the estimated parameter values of the utility functions in (2) were obtained (that is, $r(\omega_0)$ and $r(\omega_1)$ are calculated). For every outcome, $\omega \in \{\omega_0, \omega_1\}$, the utility function elicited is unique up to a positive linear transformation. The next step requires aligning the utility functions across outcomes. This involves the following simple procedure.

First we need to normalize the outcome-dependent utility functions which in general is unique up to positive linear transformation. Fix $y > x$, and let $b(\omega_0)$ and $d(\omega_0)$ be the solution to the equations

$$b(\omega_0) \left[-e^{\frac{-y^{r(\omega_0)}}{r(\omega_0)}} \right] + d(\omega_0) = 1 \quad (7)$$

and

$$b(\omega_0) \left[-e^{\frac{-x^{r(\omega_0)}}{r(\omega_0)}} \right] + d(\omega_0) = 0. \quad (8)$$

For ω_1 , let the decision maker indicate the wealth levels $x(\omega_1)$ and $y(\omega_1)$ that would leave him indifferent between the payoff-outcome pairs $(x(\omega_1), \omega_1)$ and (x, ω_0)

⁹Outcomes in these instance refer to medical conditions following the test and are not the test results.

and between the payoff-outcome pairs $(y(\omega_1), \omega_1)$ and (y, ω_0) . Formally, denote by \sim the indifference relation and let $x(\omega_1)$ and $y(\omega_1)$ be defined by $(x(\omega_1), \omega_1) \sim (x, \omega_0)$ and $(y(\omega_1), \omega_1) \sim (y, \omega_0)$.

Given $x(\omega_1)$ and $y(\omega_1)$, let $b(\omega_1)$ and $a(\omega_1)$ be the solution to the equations

$$b(\omega_1) \left[-e^{\frac{-y(\omega_1)r(\omega_1)}{r(\omega_1)}} \right] + d(\omega_1) = 1 \quad (9)$$

and

$$b(\omega_1) \left[-e^{\frac{-x(\omega_1)r(\omega_1)}{r(\omega_1)}} \right] + d(\omega_1) = 0. \quad (10)$$

Combining these results, for every x and $\omega \in \{\omega_0, \omega_1\}$, we ascribe to the patient the utility functions

$$U(x, \omega) := b(\omega) \left[-e^{\frac{-x r(\omega)}{r(\omega)}} \right] + d(\omega), \text{ for all } \omega \in \Omega. \quad (11)$$

2.4 Calibration of utility across actions

The general procedure for calibrating the utility across actions is described in Karni (2009). Considering that in the case at hand, the choice is between having the genetic test administered by expert physician, a_1 , versus average physician, a_0 , it is safe to assume that the “utility cost” of the actions, namely, the disutility associated with pain and other inconveniences, is the same across physicians¹⁰. Thus we assume that $\lambda(a_1) = \lambda(a_0)$ and $v(a_1) = v(a_0)$.

To sum up, patients’ preferences are represented by expected utility functional of the form

$$\left[b(\omega_0) \left(-e^{\frac{-(x-\varphi(a))r(\omega_0)}{r(\omega_0)}} \right) + d(\omega_0) \right] p(\omega_0 | a, c) + \left[b(\omega_1) \left(-e^{\frac{-(x-\varphi(a))r(\omega_1)}{r(\omega_1)}} \right) + d(\omega_1) \right] p(\omega_1 | a, c), \quad (12)$$

where $\varphi(a)$, $a \in \{a_0, a_1\}$ denotes the financial cost of the test performed by physician of type a .

¹⁰The term expert pertains to a physician that performs larger than average number of procedures per unit of time and, as result, has higher success rate than average physician

3 Implementation

Consider, a pregnant woman who decided to undergo prenatal diagnostic testing, CVS or amniocentesis, and must choose between an expert physician and a average physician who is less expensive, but has a higher probability of fetus loss. In this section we show how the model may be applied to aid such women to choose a physician to administer the test.

3.1 Risk assessment and physicians' costs

The difficulty of estimating of the physician's skill stems, in part, from missing data. Women who lost their fetus following an invasive diagnostic test have no reason to inform the physician who performed the test. Moreover, spontaneous miscarriages occur mostly during the first trimester, but also during the second and even the third trimester of pregnancy. In many cases, it is impossible to confirm whether the miscarriage was caused by the test. Despite these obvious difficulties, it has been shown that there is statistically significant learning associated with practice as measured by lower fetal losses and reduced need to perform several insertions.¹¹

For the purpose of this study we use the official data of the MRM 2007 - the "Israeli Medical Management Co."¹² According to these data the probabilities of continued pregnancy and fetus loss following CVS are 0.99 and 0.01, respectively (that is, $p_{CVS}(\omega_0) = 0.99$ and $p_{CVS}(\omega_1) = 0.01$). The corresponding figures for amniocentesis are 0.995 and 0.005 (that is, $p_A(\omega_0) = 0.995$ and $p_A(\omega_1) = 0.005$). We take these figures to represent the risk associated with the different tests if performed by a physician whose skill level is average. We *assume* that the corresponding probabilities if the procedures are performed by a expert physicians are twice as good as those of average physicians. Thus, for an expert physician $p_{CVS}(\omega_0) = 0.995$ and $p_{CVS}(\omega_1) = 0.005$ and $p_A(\omega_0) = 0.9975$ and $p_A(\omega_1) = 0.0025$.

The cost of performing the tests by expert and average physicians were chosen to reflect the prices in Israel in 2010. The estimated cost of CVS performed by

¹¹See Wijnberger et. al. (2000).

¹²These data are most familiar to the participants in our study since they appear on the agreement document that each woman in Israel must sign before undergoing CVS or amniocentesis.

expert physician is 4500 New Israeli Shekel (*NIS*) and the corresponding cost of amniocentesis is estimated at 3500 *NIS*. The cost of both procedures performed by average physicians in a facility of one of the HMOs is fully covered, so it taken to be zero.

3.2 Utility elicitation

For the purpose of eliciting the patients' proportional certainty equivalent, we confronted the them with the risk of winning or losing 1% of the value of their respective assets with equal probability. Formally, use a random variable, $\tilde{\varepsilon}$, that may take one of two possible values, namely, +0.01 and -0.01, with equal probability. Hence, $\sigma_{\tilde{\varepsilon}}^2 = 10^{-4}$. The relative risk premia, $\pi(x, \omega)$, were obtained by asking the subjects to state the maximal proportion of their wealth they were willing to pay to avoid the proportional risk $\tilde{\varepsilon}$, given the test outcome, ω .

3.3 Alignment of the utility functions

To align the outcome-dependent utility functions we used the solutions $r(\omega)$, $\omega \in \Omega$, to calculate the coefficients of the utility functions. Specifically, we confronted the subjects with the hypothetical scenario according to which they won 1,000,000 *NIS* and, as a result, their wealth increase from x to $y = x + 1,000,000$. We fixed $u(x, \omega_0) = 0$ and $u(y, \omega_0) = 1$ and solved for

$$b(\omega_0) = \frac{1}{-e^{\frac{-x_1(\omega_0)r(\omega_0)}{r(\omega_0)}} + e^{\frac{-x_0(\omega_0)r(\omega_0)}{r(\omega_0)}}} \quad (13)$$

and

$$d(\omega_0) = \frac{e^{\frac{-x_0(\omega_0)r(\omega_0)}{r(x_1, \omega_0)}}}{-e^{\frac{-x_1(\omega_0)r(\omega_0)}{r(\omega_0)}} + e^{\frac{-x_0(\omega_0)r(\omega_0)}{r(\omega_0)}}}. \quad (14)$$

We elicited $x(\omega_1)$ and $y(\omega_1)$ by $(x(\omega_1), \omega_1) \sim (x, \omega_0)$ and $(y(\omega_1), \omega_1) \sim (y, \omega_0)$,

as described above. and solve for $b(\omega_1)$ and $d(\omega_1)$ to obtain¹³

$$b(\omega_1) = \frac{\frac{1}{p_j(\omega_1)} \left[b(\omega_0) \left(-e^{\frac{-y(\omega_1)r(\omega_0)}{r(\omega_0)}} \right) - p_j(\omega_0) \right]}{-e^{\frac{-y(\omega_1)r(\omega_1)}{r(\omega_1)}} + e^{\frac{-x(\omega_1)r(\omega_1)}{r(\omega_1)}}} \quad (15)$$

and

$$d(\omega_1) = \frac{1}{p_j(\omega_1)} \left[b(\omega_0) \left(-e^{\frac{-y(\omega_0)r(\omega_0)}{r(\omega_0)}} \right) + d(\omega_0) \right] + b(\omega_1) e^{\frac{-x(\omega_1)r(\omega_1)}{r(\omega_1)}}. \quad (16)$$

4 Results

In this section we describe the methods used, the study population, and summarize the main general findings.

4.1 Methods and the study population

The study was conducted through “LimeService,” a survey service platform for running online surveys, in Hebrew, from December 2008 through December 2009. It included two anonymous separate questionnaires, one for CVS and one for amniocentesis. Links to the CVS questionnaire in private mode (the record kept does not contain any identifying information about the survey responses) were sent, by e-mail, to doctoral and MBA students from Tel Aviv University. Links to the amniocentesis questionnaire, in private mode, were posted in four pregnancy and labor internet forums.

The online questionnaires (both for CVS and amniocentesis) included eighteen questions (see Appendix). The questionnaires were identical except for the descriptions of the procedures and the corresponding fetus loss probabilities. The first question was only use to encourage the participants to keep on answering questions. The

¹³More specifically, we solved the equations:

$$p_j(\omega_0) u(y, \omega_0) + p_j(\omega_1) u(y, \omega_1) = u(y(\omega_1), \omega_0)$$

and

$$p_j(\omega_0) u(x, \omega_0) + p_j(\omega_1) u(x, \omega_1) = u(x(\omega_1), \omega_0),$$

where $j \in \{CVS, A\}$, to obtain

$$b(\omega_1) u(y, \omega_1) + d(\omega_1) = \frac{u(y(\omega_1), \omega_0)}{p_j(\omega_1)} = \frac{1}{p_j(\omega_1)} \left[b(\omega_0) \left(-e^{\frac{-y(\omega_1)r(\omega_0)}{r(\omega_0)}} \right) + d(\omega_0) - p_j(\omega_0) \right]$$

$$\text{and } b(\omega_1) u(x, \omega_1) + d(\omega_1) = \frac{u(x(\omega_1), \omega_0)}{p_j(\omega_1)} = \frac{1}{p_j(\omega_1)} \left[b(\omega_0) \left(-e^{\frac{-x(\omega_1)r(\omega_0)}{r(\omega_0)}} \right) + d(\omega_0) \right].$$

next five questions were mandatory, and were design to elicit the information necessary to calculate the parameter values of the utility functions (that is, $r(\omega_0)$ and $r(\omega_1)$). The last twelve questions were optional and intended to collect demographic and medical information to be used in the statistical analysis. The demographic questions, with minor changes, were taken from surveys of Israel's Central Bureau of Statistics.

A total of 176 women started to fill in the online questionnaire, 94 of which responded to the CVS questionnaire and 82 responded to the amniocentesis questionnaire. Seventy women (74%) completed the mandatory questions in the CVS study and 40 women (49%) completed the amniocentesis questionnaire.¹⁴

4.2 Unreasonable Behavior

The first question that concerns us is to what extent the responses are consistent with the underlying tenets of the model. Responses were qualified as unreasonable given the model include (a) lower willingness to pay extra for testing that involve no risk of fetus loss when the responder is richer than when she is poorer, (b) willingness to pay to avoid financial risk equal to the largest possible loss associated with that risk. Responses of these types suggest that the respondents either were not paying attention or didn't understand the task they were asked to perform.

Examination of the responses shows that non of the participants in either study were unreasonable according to (a) and only 9% of the respondents in the CVS study and 3% of the participants in the amniocentesis study were qualified as unreasonable according to (b). Thus, broadly speaking, the participants in the study seem able to give useful answers.

We note that the values of the parameters $r(\omega)$ that determined the risk attitudes exhibit no systematic pattern that can be explained by demographic or medical characteristics in the subject population. We found that in the population there were patients displaying higher risk aversion in state ω_0 than in ω_1 . There were patients displaying the opposite pattern of risk attitude. And there were patients whose risk

¹⁴Partial responses were checked. No specific question was found in which the respondents quit the online questionnaires.

attitude were outcome independent.

5 The Model as a Decision-Making Tool: Case Studies

The main objective of this work is to study the possibility of using the model and procedures such as the one described here to help doctors and patients make medical decision. The choice facing the women in this study is between undergoing a prenatal diagnostic test with an average physician and an expert physician. To illustrate how our method works in this context, we describe below four participants in the CVS study who display outcome-dependent risk attitudes. In each case, the graphs of two utility functions, corresponding to the two outcomes, ω_0 and ω_1 , are displayed and the maximum price that a women should be ready to pay to have the procedure done by an expert physician as opposed to an average physician is calculated, based on her utility functions. This is followed by a recommended course of action, namely, a recommendation on whether to have the test administered by an expert or an average physician, given the prices charged by these physician . Throughout we assume that the price of having the test administered by an expert is 4500 *NIS*. We consider two alternative costs of having the test administered by an average physician, a full subsidy which means that the patient pays nothing and partial subsidy in which the patient pays 570 *NIS*.

Recall that the medical risk involved if the CVS procedure is performed by an average physician was estimated at $p_{CVS}(\omega_1) = 1\%$.

5.1 Case 1: Patient of type 1 - $r(\omega_0) > r(\omega_1)$

The patient initial wealth is $x = 1,500,000$ *NIS* and in the study she was asked to envision gaining one million *NIS* so that her wealth increased to $y = 2,500,000$ *NIS*. This patient indicated her willingness to pay the proportional premia $\pi(\omega_0, x) = 0.5$ and $\pi(\omega_1, x) = 0$ to avoid the proportional risk $\tilde{\varepsilon}$. Thus, her implied parameter values are $r(\omega_0) = 0.32$ and $r(\omega_1) = 0.21$.

The patient also indicated willingness to pay 6000 *NIS* at x and 10,000 *NIS* at y to avoid the risk of miscarriage as a result of the test altogether. Consequently, $y_0 = 1,494,000$ and $y_1 = 2,490,000$. Hence, the alignment of the outcome-dependent

utility functions implies that $d(\omega_0) = 1.00$, $b(\omega_0) = 1.37857 \times 10^{40}$, $d(\omega_1) = 6.25$, and $b(\omega_1) = 5.2308 \times 10^{296}$ (see Figure 1 below).

We simulated cost and the recommended course of action for three types of experts, namely, experts whose probabilities inducing involuntary abortion are 0.5%, 0.25% and 0.01%. The findings are summarized in the following table:

	Average physician	Average physician	Recommendation
	Free	570 NIS	(In both cases)
$p_{CVS}(\omega_1) = 0.5\%$	3,186 NIS	3,671 NIS	Average physician
$p_{CVS}(\omega_1) = 0.25\%$	4,636 NIS	4,500 NIS	Expert physician
$p_{CVS}(\omega_1) = 0.1\%$	5,646 NIS	4,500 NIS	Expert physician

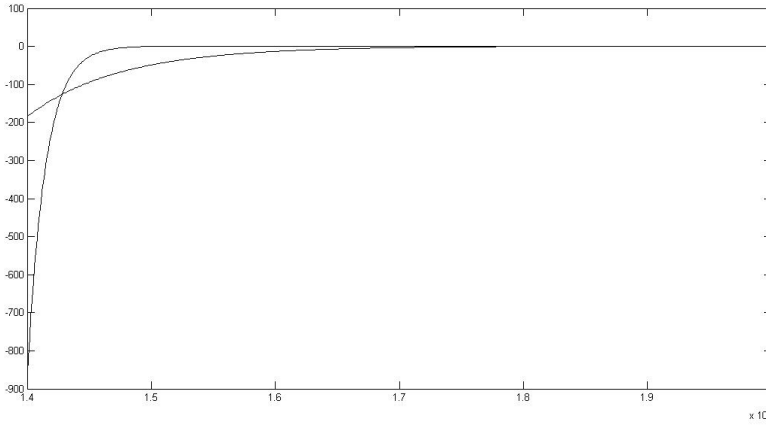


Figure 1: State Dependent Patient, Type 1 ($r_0 > r_1$) ($u_{\omega 1}$ and $u_{\omega 2}$)

5.2 Case 2: Patient of type 1 - $r(\omega_0) > r(\omega_1)$

The patient initial wealth is $x = 3,000,000$ NIS and in the study she was asked to envision gaining one million NIS so that her wealth increased to $y = 4,000,000$. This patient indicated her willingness to pay the proportional premia $\pi(\omega_0, x) = 0.3$ and $\pi(\omega_1, x) = 0.2$ to avoid the proportional risk $\tilde{\varepsilon}$. Thus, her implied parameter values are $r(\omega_0) = 0.27$ and $r(\omega_1) = 0.25$.

The patient also indicated willingness to pay to avoid the risk altogether of miscarriage as a result of the test 1500 NIS at x and 1,500 NIS at y . Consequently,

$y_0 = 3,985,000$ and $y_1 = 4,985,000$. Hence, the alignment of the outcome dependent functions implies that $d(\omega_0) = 1.00$, $b(\omega_0) = 1.11516 \times 10^{94}$, $d(\omega_1) = 1.00$, and $b(\omega_1) = 7.487988403491 \times 10^{69}$ (see Figure 2 below).

The cost and the recommended course of action for tree types of experts, namely, experts whose probabilities inducing involuntary abortion are 0.5%, 0.25% and 0.01% are summarized in the following table:

	Average physician	Average physician	Recommendation
	Free	570 NIS	(In both cases)
$p_{CVS}(\omega_1) = 0.5\%$	750 NIS	1,316 NIS	Average physician
$p_{CVS}(\omega_1) = 0.25\%$	1,125 NIS	1,689 NIS	Average physician
$p_{CVS}(\omega_1) = 0.1\%$	1,350 NIS	1,913 NIS	Average physician

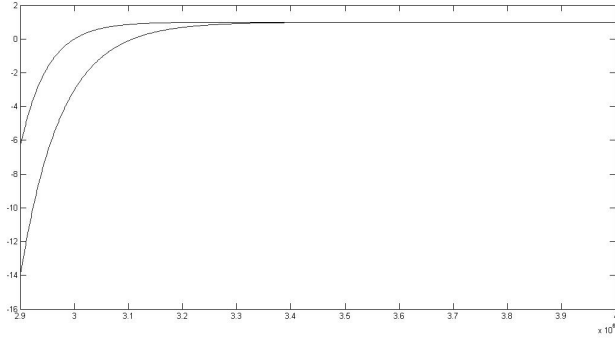


Figure 2: State Dependent Patient, Type 1 ($r_0 > r_1$) (u_{ω_1} and u_{ω_2})

5.3 Case 3: Patient of type 2 - $r(\omega_0) < r(\omega_1)$

The patient initial wealth is $x = 850,000$ NIS and in the study she was asked to envision gaining one million NIS so that her wealth increased to $y = 1,850,000$. This patient indicated her willingness to pay the proportional premia $\pi(\omega_0, x) = 0.2$ and $\pi(\omega_1, x) = 0.9$ to avoid the proportional risk $\tilde{\varepsilon}$. Thus, her implied parameter values are $r(\omega_0) = 0.27$ and $r(\omega_1) = 0.38$.

The patient also indicated willingness to pay to avoid the risk altogether of miscarriage as a result of the test 4,000 NIS at x and 25,000 NIS at y . Consequently,

$y_0 = 846,000$ and $y_1 = 1,825,000$. Hence, the alignment of the outcome dependent functions implies that $d(\omega_0) = 1.0$, $b(\omega_0) = 2.747044031E + 63$, $d(\omega_1) = 1.0$, and $b(\omega_1) = 1.92374413647E + 206$. (see Figure 3 below).

The cost and the recommended course of action for tree types of experts, namely, experts whose probabilities inducing involuntary abortion are 0.5%, 0.25% and 0.01% are summarized in the following table:

	Average physician	Average physician	Recommendation
	Free	570 NIS	(In both cases)
$p_{CVS}(\omega_1) = 0.5\%$	1,381 NIS	2,034 NIS	Average physician
$p_{CVS}(\omega_1) = 0.25\%$	2,403 NIS	3,141 NIS	Average physician
$p_{CVS}(\omega_1) = 0.1\%$	3,248 NIS	4,079 NIS	Average physician

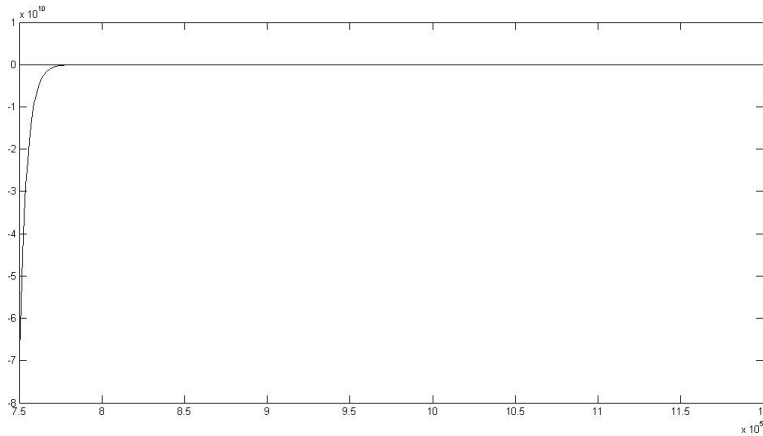


Figure 3: State Dependent Patient, Type 1 ($r_0 < r_1$) (u_{ω_1} and u_{ω_2})

5.4 Case 4: Patient of type 2 - $r(\omega_0) < r(\omega_1)$

The patient initial wealth is $x = 1,500,000$ NIS and in the study she was asked to envision gaining one million NIS so that her wealth increased to $y = 2,500,000$. This patient indicated her willingness to pay the proportional premia $\pi(\omega_0, x) = 0.1$ and $\pi(\omega_1, x) = 0.3$ to avoid the proportional risk $\tilde{\varepsilon}$. Thus, her implied parameter values are $r(\omega_0) = 0.21$ and $r(\omega_1) = 0.29$.

The patient also indicated willingness to pay to avoid the risk altogether of mis-carriage as a result of the test 2,000 *NIS* at x and 2,000 *NIS* at y . Consequently, $y_0 = 1,498,000$ and $y_1 = 2,498,000$. Hence, the alignment of the outcome dependent functions implies that $d(\omega_0) = 1.0$, $b(\omega_0) = 2.50253252 \times 10^{133}$, $d(\omega_1) = 1.0$, and $b(\omega_1) = 1.780306732636 \times 10^{90}$. (see Figure 4 below).

The cost and the recommended course of action for tree types of experts, namely, experts whose probabilities inducing involuntary abortion are 0.5%, 0.25% and 0.01% are summarized in the following table:

	Average physician	Average physician	Recommendation
	Free	570 NIS	
$p_{CVS}(\omega_1) = 0.5\%$	958 NIS	1,547 NIS	Average physician in both cases
$p_{CVS}(\omega_1) = 0.25\%$	1,467 NIS	4,500 NIS	Average physician Expert if subsidized
$p_{CVS}(\omega_1) = 0.01\%$	1,784 NIS	4,500 NIS	Average physician Expert if subsidized

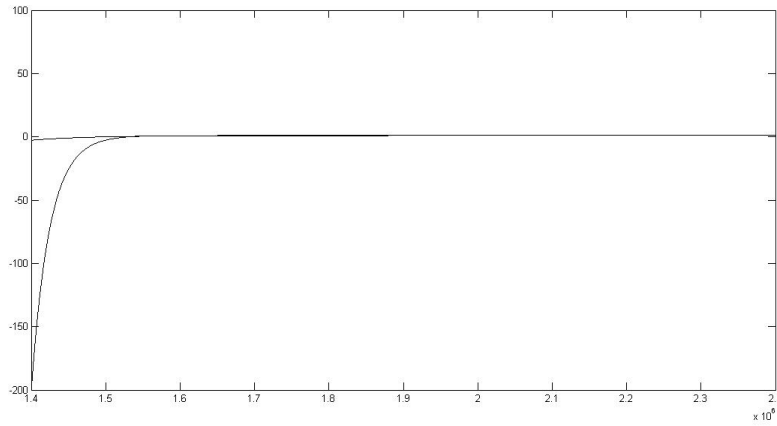


Figure 4: State Dependent Patient, Type 1 ($r_0 < r_1$) (u_{ω_1} and u_{ω_2})

6 Conclusions

The first main conclusion is that, for a large majority of the subjects participating in this study, the answers are not inconsistent with the basic premises of the decision

model. This suggests that the subjects are capable to provide evaluations that can be used in the application of the model, and that, properly applied, the model is a useful instrument to help make medical decisions.

For most subjects the risk attitudes do not depend on the outcome, and for those it does, it has no particular tendency. This suggests that, since involuntary abortion does not have long term physical health consequences, such as reduced earning ability, the attitudes towards risk are unaffected¹⁵.

Health-dependent risk attitudes may prove to be more important when the a treatment alters the health state permanently, or for a significant period of time, with consequences for the earning ability. We also note that, in the cases studied in detail, the subjects displayed decreasing absolute risk aversion and increasing relative risk aversion¹⁶.

For a large majority of the study population whose responses did not conflict with the underlying premises of the model, it produced recommendations about which course of action that best serves the interests of the subjects which is normatively compelling.

The generality of our conclusion is limited in two respects. First, for the sake of simplicity, we ignored the extremely rare outcome of maternal death as a result of CVS and amniocentesis. Second, the study population is rather homogenous, which may explain the fact that we found no clear distinctions in risk attitudes and between participants in CVS and amniocentesis group according to social-economic measures. In this sense, the study is not representative of the wide spectrum of pregnant women in Israel.

¹⁵Rarely abortions may have long term consequences such as loss of ability to bear children. We did not consider this possibility as an element of our set of outcomes.

¹⁶Note that this characterization of risk attitude is consistent with plausible behavior. A fact that lends credence to our measurement method.

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CVS questionnaire

Question 1: During your current/last pregnancy, who managed your pregnancy supervision?

- ☐ Mother and child care
- ☐ Gynecologist, as part of healthcare services
- ☐ Private gynecologist
- ☐ None
- ☐ Other

Imagine a state in which you have decided to have chorionic villus sampling (CVS) at the recommendation of your attending physician. This examination is not recommended in the state of routine pregnancy, but it has been recommended to you following certain tests that you have had (such as genetic profiling).

Chorionic villus sampling is a test that is performed through the abdomen or through the vagina and cervix and provides information on the fetus' condition. The results of the test allow one to know whether the fetus has one or more of the following genetic conditions: cystic fibrosis, Down syndrome, sickle cell anemia, fragile X syndrome.

After performing the test there is a risk of miscarriage (as a result of testing). The physician's skill and experience have an effect over the chances of miscarriage. When a physician of average skill performs the test, there is a chance of 1 in every 100 women undergoing it miscarrying as a result (1% miscarriage rate).

The possible complications of the test (other than miscarriage) include: In rare cases, physical injury to the fetus and infection that may require hysterectomy and in rare cases may be life threatening.

Question 2: deals with an imaginary state in which you have decided to undergo chorionic villus sampling (CVS) following the recommendation of your attending physician

Assume now that you have been offered another test that has no risk (0% risk) of miscarriage, that provides all of the information that chorionic villus sampling (CVS) provides.

What is the highest sum that you would be willing to pay in shekels for this test (without any risk for miscarriage)? NIS

* Specify the sum that you would be willing and able to pay.

Imagine that you have won a million (1,000,000) shekels in the lottery

Question 3: relates to an imaginary state in which you have decided to have chorionic villus sampling (CVS) following the recommendation of your attending physician and after having won a million shekels on the lottery!

Say now that you have been offered another test that has no risk (0% risk) for miscarriage, which provides all of the information that chorionic villus sampling (CVS) provides.

What is the highest sum that you would be willing to pay in shekels (after having won the lottery) for this test (without any risk of miscarriage)? NIS

Question 4: deals with personal details. These details are anonymous and are not identified.

Generally, what is your total amount of assets?

* Your order of magnitude of assets, for example apartment, vehicle and savings minus mortgage and loans. If you are married or live with someone it refers to the total assets belonging to both of you.

- ☐ Up to and including NIS 100,000
- ☐ NIS 100,001 - 300,000
- ☐ NIS 300,001 - 500,000
- ☐ NIS 500,001 - 700,000
- ☐ NIS 700,001 - 1,000,000
- ☐ NIS 1,000,001 - 2,000,000
- ☐ More than NIS 2,000,000

Questions 5-6: relate to financial preferences (your willingness to bet a certain sum of money) in two very different medical conditions

Question 5 deals with your willingness to bet on the following medical condition:

Imagine that about three weeks after your having undergone chorionic villus sampling (CVS) and your pregnancy continuing normally, you receive the results of the test by mail and they are all in order.

The meaning of this is that your unborn child does not have one of the following genetic diseases: Down syndrome, cystic fibrosis, sickle cell anemia, fragile X syndrome

5. You must now participate in a draw in which you may win NIS 1,000 or lose NIS 1,000. Your chances of winning or losing are even (50%).

How much would you be willing to pay (if at all) not to participate in this draw? NIS

* Based on the answer to question 4 - up to NIS 100,000

- ☐ Willing to pay NIS 0 - I prefer to participate in draw
- ☐ Willing to pay up to NIS 200 (not inclusive) - to avoid draw participation
- ☐ Willing to pay NIS 200 - 400 (not inclusive) - to avoid draw participation
- ☐ Willing to pay NIS 400 - 600 (not inclusive) - to avoid draw participation
- ☐ Willing to pay NIS 600 - 800 (not inclusive) - to avoid draw participation

- ☐ Willing to pay NIS 600 - 800 (not inclusive) - to avoid draw participation
- ☐ Willing to pay NIS 800 - 1000 (not inclusive) - to avoid draw participation
- ☐ Willing to pay NIS 1000 - to avoid draw participation

Question 6 deals with your willingness to bet on the following medical condition:

Imagine that about a week after performing chorionic villus sampling (CVS), you miscarry. Two weeks later you receive the results of the test by mail and they are normal.

The meaning of this is that your unborn child did not have any of the following genetic diseases: Down syndrome (DS), cystic fibrosis (CF), sickle cell anemia (SC), fragile X syndrome (FX).

*Note that in exceptional cases, such a miscarriage may mean that you will not be able to become pregnant again.

6. You must now participate in a draw in which you may win NIS 1,000 or lose NIS 1,000. Your risks of winning or losing are equal (50%)

How much would you be willing to pay (if at all) in order not to participate in this draw? NIS

* Based on the answer to question 4 - up to NIS 100,000

- ☐ Willing to pay NIS 0 - I prefer to participate in draw
- ☐ Willing to pay up to NIS 200 (not inclusive) - to avoid draw participation
- ☐ Willing to pay NIS 200 - 400 (not inclusive) - to avoid draw participation
- ☐ Willing to pay NIS 400 - 600 (not inclusive) - to avoid draw participation
- ☐ Willing to pay NIS 600 - 800 (not inclusive) - to avoid draw participation
- ☐ Willing to pay NIS 600 - 800 (not inclusive) - to avoid draw participation
- ☐ Willing to pay NIS 800 - 1000 (not inclusive) - to avoid draw participation
- ☐ Willing to pay NIS 1000 - to avoid draw participation

Questions 7-18 deal with anonymous personal details that are used for collective statistic analysis only

7. Age:

☐ Above 40 ☐ 36-40 ☐ 31-35 ☐ 26-30 ☐ Below 26

8. Religion:

☐ Other ☐ Druze ☐ Christian ☐ Muslim ☐ Jewish

9. Sector:

☐ Orthodox Jew ☐ Religious ☐ Traditional ☐ Agnostic

10. Education (what is your highest diploma or academic degree):

☐ Without matriculation certificate
☐ Matriculation certificate
☐ Tertiary education (not academic) as practical engineer and teacher's certificate
☐ Academic- bachelor's degree
☐ Academic - master's degree
☐ Academic - doctorate

11. Marital status:

☐ Married ☐ Separated ☐ Divorced ☐ Widow
☐ Single ☐ Common law relationship ☐ Other

12. Are you get paid for your work? ☐ Yes ☐ No

*If you are on maternity leave - mark Yes

If the answer to question 12 was "No", the next question that the respondent will be shown is question 17

13. Are you currently working? ☐ Yes ☐ No

*If you are on maternity leave - mark Yes

14. What is our status at work?

☐ Salaried employee
☐ Employer
☐ Self-employed
☐ Cooperative member
☐ Kibbutz member
☐ Other

14. What is the economic sector to which the establishment or institute you are working at belongs?

14. What is the economic sector to which the establishment or institute you are working at belongs?

- ☐ Public administration
- ☐ Education
- ☐ Healthcare services (healthcare services and welfare)
- ☐ Community services (community services, social, personal and others)
- ☐ Industry (High Tech, electronics, chemistry, food, beverage and tobacco, textile, light industry etc.)
- ☐ Banking, insurance and financial institute
- ☐ Business services (real estate, equipment renting, bookkeeping, accounting security and cleaning) Commerce (wholesale and retail)
- ☐ Hospitality and food services
- ☐ Building (building and civil engineering)
- ☐ Transport, storage and communication
- ☐ Agriculture
- ☐ Electricity and water

15. Number of children:

16. Are you currently pregnant? ☐ Yes ☐ No

17. Have you ever had any kind of abortion? ☐ Yes ☐ No

18. Are you familiar with someone who has the following birth defects: Down syndrome, cystic fibrosis, sickle cell anemia and fragile X? ☐ Yes ☐ No

Thank you for participating in the research
