On the Economics of Rational Self-Medication

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Summary

It has been established in the medical literature that self-medicating with imperfect information about either the use of a genuine or counterfeit drug or based on wrong self-diagnosis of ailment, which is predominant especially in developing countries, is a risky investment in health capital. This paper models the decision to self-medicate and the demand for self-medicated drugs. We suppose that investment in self-medication depends on the perception of its effectiveness. The results obtained show that the decision to self-medicate depends on the relative price and perceived effectiveness of self-medication, the elasticity of the shadow value of health with respect to the quantity of health capital, and the relative effectiveness of self-medication in reducing the unpredictable changes in health capital. Furthermore, if an individual self-medicates, self-medication becomes a normal good: it increases if income increases; and it obeys the law of demand (i.e. it increases if its price, relative to that of the risk-free medication, decreases). Moreover, we have shown that some optimum subsidy can discourage self-medication.

Keywords: Health Production, Self-Medication, Risky Investment, Government Policy, Dynamic Analysis

JEL Classification: I12, I18, D81, C61

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1. Introduction

While *responsible* self-medication, which is limited to over-the-counter (OTC) drugs, may generate substantial net benefit flows to economies through savings in travel and consultation time and the direct financial cost of treatment (AESGP, 2004), some conditions are necessary for these benefits to be realized. These conditions aim at ensuring the safety of taking self-medicated drugs. They include the following: the drugs used are those indicated for conditions that are self-recognizable; the user should know how to take or use the drugs; the effects and possible side-effects of the drugs as well as ways of monitoring these side-effects are well communicated to the user; possible interactions with other drugs is known by the user; duration of the course of the drugs is known by the user and, when the user must seek professional intervention (WHO, 1998). The consequences for incorrect diagnosis and dosage include growing resistance to some drugs and further deterioration in health capital.

Unfortunately, especially in developing countries, professional health care is relatively expensive and in some cases not readily available thereby making self-medication an obvious choice of health care service (Chang and Trivedi, 2003; Phalke et al., 2006). Furthermore, it has been noted that purchases of prescription-only drugs are far more than the purchase of OTC drugs (Chang and Trivedi, 2003; WHO, 2001) and many drugs that can only be purchased with prescription in developed countries are OTC in developing countries (Chang and Trivedi, 2003). Also, lax medical regulations have resulted in the proliferation of counterfeit drugs that are in high demand for the treatment of highly prevalent diseases such as malaria (see e.g. Shakoor et al., 1997; WHO, 1999; Rogendaal, 2001; Basco, 2004). For example, a study by Basco (2004) in Africa on the use of chloroquine, quinine and antifolates showed that about 30%, 74% and 12% of these malaria drugs respectively had either no active ingredient, insufficient active ingredient, the wrong ingredient or an unknown ingredient. Moreover, a considerable number of studies have also highlighted the potential dangers of self-medication (Levy, 1992; Mudur, 1999; WHO, 2001). As a result, taking a self-medicated drug is a risky investment in health capital[1].

Although self-medication is very common and expected to grow as a result of the use of the internet to market drugs and deregulation of OTC sale of drugs with *active* ingredients (see e.g. Chang and Trivedi, 2003; Phalke et al., 2006), economic models for such a risky investment in health capital are very scarce. The only attempt at modeling the economics of self-medication is by Chang and Trivedi (2003) who developed a static model based on choice under uncertainty. In their model, the individual allocates her budget between the consumption of a composite good, a self-medicated drug and professional care. While professional care is assumed to be risk-free, self-medication is not. The main results from their theoretical model are as follows: First, self-medication obeys the law of demand. Second, self-medication is an inferior good. Third, riskier self-medication will increase the demand for professional care. While the first and the third results were confirmed by their data, they found that self-medication was a normal good for the low-income group (i.e. 50th percentile) and an inferior good for the high-income group. Like Chang and Trivedi (2003), this paper assumes that the individual maximizes utility from consuming a composite good and a state of health. However, we extend this work in a number of ways. First, since health capital is a state variable that evolves overtime in a partly uncertain manner due to unexpected ailments, we present the state of health equation as a stochastic dynamic equation (see e.g. Grossman, 1972; Cropper, 1977; Reid, 1996; Picone et al., 1997; Sidorenko, 2001 for stochastic models of health); second, total expenditure on medication within a period of time is the expected expenditure on self-medication and risk-free medication, where the probability weights are based on the individual's perception of the effectiveness of the self-medicated drug and the risk-free medication[2]; third, the expected health benefit from self-medication depends on perceived effectiveness of self-medication. Moreover, in this paper, the marginal conditions in the presence of self-medication and risk-free medication only have been compared to determine the optimal subsidy necessary to discourage self-medication.

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[1] Self-medication is considered risk-free if and only if it is limited to an OTC drug that is not counterfeited.

[2] Note that commitment to self-medication only is not feasible, since the individual has to resort to prescribed medication if self-medication fails.

The results obtained from the optimization program indicates that the decision to self-medicate depends on the relative price of the two medications (i.e. an individual may switch to self-medication if it becomes relatively cheap), the perceived effectiveness of self-medication, the elasticity of the shadow value of health with respect to the quantity of health capital and the relative effectiveness of self-medication in reducing the uncertain component of the dynamics of the health capital. Furthermore, our results illustrate that self-medication is a normal good for those who engage in it: thus, it increases if income increases; and it obeys the law of demand (i.e. it increases if its relative price decreases). Finally, the optimal subsidy that can discourage self-medication must be decreasing in both the relative price and the perceived effectiveness of the self-medicated drug but increasing in the elasticity of the shadow value of the health with respect to the quantity of health capital, if the self-medicated drug is more effective in reducing the unexpected shocks to health capital. On the other hand, if the two medications are equally effective in reducing the stochastic component of the dynamics of the health capital, the subsidy is just the price difference between the two medications.

The rest of the paper is organized as follows: The model is presented in section 2 followed by the economic policy instrument in section 3. The last section presents the conclusions and the discussions of the paper.

2. The model

A stochastic model of self-medication: finding the optimal usage

Suppose a representative individual derives utility $u(c,h)$ from her state of health h and the consumption of a composite good c. Furthermore, assume that the utility is increasing in the two arguments (i.e. $u_h > 0, u_c > 0$, where the subscripts denote partial derivatives), the individual's life expectancy is T years, and future states of health is discounted at the rate δ, $\delta > 0$. The objective function of the individual is to maximize the expected value of the discounted stream of utility (i.e. equation 1), where E is an expectation operator.

$$\underset{c}{Max} \quad V = E\int_0^T u(c,h)e^{-\delta t}dt\,, \tag{1}$$

where $c \geq 0,\ h \geq 0$. Let the health capital or the state of health evolve according to a stochastic dynamic process defined by the function:

$$dh = \left(s(y,g) - \alpha\right)hdt - \sigma\left(s(y,g)\right)hdz\,, \tag{2}$$

where $y \geq 0,\ g \geq 0,\ m > 0,$ and $h(0) = h_0$.

From this equation, $s = s(y,g)$ is the health benefit from self-medicated and risk-free (e.g. prescribed) drugs (i.e. y and g, respectively) used by the individual and the constant α is the net natural depreciation of the health capital. The term $\sigma(.)$ defines the volatility or the variance of the health state dynamics, z is a Weiner process and dz is the change in the stochastic process. Note that we assume that the variance is linearly related to s, with a drift term. Thus, the equation has a deterministic component, which is the first term in the right hand side, and a stochastic or uncertain component, which is the last term of the right hand side. Beginning with the seminal paper of Grossman (1972), a number of studies have modeled health state as a dynamic process (see e.g. Picone et al., 1998). Also, Arrow (1963) introduced uncertainty in the incidence of illness in health care delivery. A number of studies have combined uncertainty and dynamics in modeling health capital (see e.g. Picone et al., 1998; Sidorenko, 2001).

The individual has to complement self-medication with professional medical care if the self-medication fails. As a result, the agent cannot solely depend on self-medication. Let m be real disposable income within a period of time t; p and q are perfect competitive relative prices of the composite good c and self-medicated drug y respectively, with risk-free medication g being the numeraire. Furthermore, let v be a subjective probability defining how effective the self-medicated drug is perceived to be. If it is perceived to be as effective as the prescribed drug, then $v = 1$ and the agent is indifferent between using a self-medicated or prescribed drug. Consequently, the agent will invest in only a self-medicated drug if it is less expensive (i.e. $m = qy + pc$ if all the budget is spent). On the other hand, if the self-medicated drug is perceived to be completely ineffective then $v = 0$, which implies that only the prescribed drug will be purchased. However if self-medication is present but the drug is perceived not to be completely effective, then $v \in (0,1)$. Therefore the term $qvy + (1-v)g$ defines expected expenditure on medication if self-medication is present. Note that the expenditure on the self-medicated drug increases as v increases. The budget constraint facing the agent within a period of time, say one year, is:

$$m = pc + qvy + (1-v)g \ . \tag{3}$$

We have supposed for simplicity, but without compromising generality, that there is no inter-temporal transfer of income between periods[3]. Moreover, the equation assumes that the entire budget is expended within each period. Note that although the expenditure on either the self-medicated drug or prescribed drug is stochastic, the probability is just a weight, which defines how the budget on the drugs is allocated. Consequently, the expected and actual expenditure should be equal in each period. Thus, like Chang and Trivedi (2003) a partial equilibrium approach is taken to model demand for health where the representative agent allocates her entire disposable income to health care and other composite commodities within each period. Moreover, it is supposed that the state of health does not affect the disposable income. It is noteworthy that this mimics the situation in many economies (especially developing countries) where fixed-income earners e.g. salary workers who receive fixed disposable income hardly save or have easy access to credit from formal financial institutions to finance consumption. It is also noted that the poor in developing countries hardly save or have easy access to credit (Aryeetey, 1994).

The Bellman equation associated with equations (1) through (3) writes

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[3] The budget constraint has been specified as wealth (w) dynamic equation by some studies, e.g. Picone (1998). In our case it could be specified as $dw = \left(rw - pc - vqy - (1-v)g \right) dt$. If it is assumed for simplicity that $dw/dt = 0$ and $rw = m$, then equation (3) is obtained.

$$\delta V = \max\left\{u(c,h) + \frac{1}{dt}E\left(dV(h)\right)\right\}. \tag{4}$$

Using Ito's lemma, we have the following definition

$$dV = \frac{\partial V}{\partial h}dh + \frac{1}{2}\frac{\partial^2 V}{\partial h^2}\left(dh\right)^2, \tag{5}$$

By substituting dh from equation (2) into equation (5), we have

$$dV = \left(\left(s(y,g) - \alpha\right)hdt - \sigma\left(s(y,g)\right)hdz\right)\frac{\partial V}{\partial h} + \frac{1}{2}\left(\left(s(y,g) - \alpha\right)hdt - \sigma\left(s(y,g)\right)hdz\right)^2 \frac{\partial^2 V}{\partial h^2}$$

(5´)

If equation (5´) is expanded, noting that for Weiner processes the following apply: $dtdt = 0$, $dzdz = dt$, $E\left(dz\right) = 0$ and $dtdz = 0$, we have

$$\frac{1}{dt}E\left(dV(h)\right) = \left(\tilde{s} - \alpha\right)h\frac{\partial V}{\partial h} + \frac{1}{2}\frac{\partial^2 V}{\partial h^2}h^2 E\sigma(s)^2, \tag{6}$$

where $E(s) = \tilde{s}$. Using equation (6), the Bellman's equation can be rewritten as

$$\delta V = \max_c\left\{u(c,h) + \left(\tilde{s} - \alpha\right)h\frac{\partial V}{\partial h} + \frac{1}{2}E\sigma(s)^2 h^2 \frac{\partial^2 V}{\partial h^2}\right\}. \tag{7}$$

Following Xepapadeas (1997), the corresponding current value Hamiltonian representation of equation (7) is equation (8). Note that $\lambda = \frac{\partial V}{\partial h}$ is the shadow value of the state of health. Moreover, since the disposable income is fixed, equation (9) represents the Lagrangean function for the optimization program, which is the sum of the current value Hamiltonian and the budget constraint.

$$H = u(c,h) + \lambda\left(\tilde{s} - \alpha\right)h + \frac{1}{2}E\sigma(s)^2 h^2 \lambda_h . \tag{8}$$

$$L = H + \omega\left(m - pc - vqy - (1-v)g\right). \tag{9}$$

The first order condition of equation (9) with respect to the choice variables: c, y and g; and the Lagrangean multiplier ω are equations (10) through (13) respectively. The corresponding costate equation is equation (14).

$$u_c = \omega p . \tag{10}$$

$$v\omega q = \lambda h s_y + h^2 \lambda_h E\sigma_s s_y . \tag{11}$$

$$\omega(1-v) = \lambda h s_g + h^2 \lambda_h E\sigma_s s_g . \tag{12}$$

$$\frac{\partial L}{\partial \omega} = 0 \rightarrow m = pc + vqy + (1-v)g . \tag{13}$$

$$\delta \frac{\partial V}{\partial h^*} = u_c + \left(s - \alpha\right)\frac{\partial V}{\partial h^*} + \sigma(\tilde{s})^2 h^* \frac{\partial^2 V}{\partial h^{*2}} + \frac{1}{dt}E\left(d\,\frac{\partial V}{\partial h^*}\right), \tag{14}$$

or

$$\dot{\lambda} - \delta\lambda = -\frac{\partial L}{\partial h^*} = -\left(\frac{\partial H}{\partial h^*}\right) = \left(\alpha - s\right)\lambda - \sigma(s)^2 h^* \lambda_h - u_h .$$

The interpretation of equation (10) is straightforward: in equilibrium, the marginal utility obtained from consuming the composite good (i.e. $u_c = \frac{\partial u(.)}{\partial c}$) should be equal to the utility of the price of the good (i.e. ωp). Rewriting equations (11) and (12), and using equation (10) gives

$$\tilde{s}_y = \frac{vqu_c}{\lambda ph\left(1 + \eta E\sigma_s\right)} \quad . \tag{11´}$$

$$\tilde{s}_g = \frac{u_c\left(1-v\right)}{\lambda ph\left(1+\eta E\sigma_s\right)}. \qquad (12')$$

where $\eta = \frac{\lambda_h h}{\lambda}$ is the elasticity of the shadow value of health with respect to the quantity of health capital (i.e. how sensitive the value an individual places on her health capital is to a change in her state of health). Consequently, the weighted sum of the marginal health benefits if self-medication is present is

$$\tilde{s}_y + \tilde{s}_g = \frac{u_c}{h}\left(\frac{v(q-1)+1}{\lambda p\left(1+\eta E\sigma_s\right)}\right). \qquad (15)$$

From equation (15), the expected health benefit from a marginal increase in the use of the self-medicated and prescribed drugs (i.e. $\tilde{s}_y + \tilde{s}_g$) must reflect some adjusted marginal opportunity cost of the composite good per unit of the health capital (i.e. the term at the right hand side of the equation). Note that v and $E\sigma_s$ appear in equation (15) due to the individual's perceived uncertainty about how effective the self-medicated drug is and the uncertainty about the health dynamics of her health capital respectively.

Risk-free medication

If the individual does risk-free medication, the optimization program becomes maximizing equation (1) subject to the following constraints

$$dh = \left(w(g)-\alpha\right)hdt - \sigma\left(w(g)\right)hdz, \qquad (16)$$

$$m = pc + g, \qquad (17)$$

where $w = w(g)$ is the health benefit from risk-free medication only. The corresponding Bellman's equation is equation (18), and the Hamiltonian and the Lagrangean functions are equations (19) and (20) respectively.

$$\delta V = \max_c \left\{ u(c,h) + \left(w - \alpha h\right)\frac{\partial V}{\partial h} + \frac{1}{2}\sigma(w)^2 h^2 \frac{\partial^2 V}{\partial h^2} \right\}. \tag{18}$$

$$H = u(c,h) + \lambda\left(w - \alpha h\right) + \frac{1}{2}\sigma(w)^2 h^2 \lambda_h. \tag{19}$$

$$L = H + \omega\left(m - pc - g\right). \tag{20}$$

The first order derivative of equation (20) with respect to c and g gives equations (21) and (22), respectively.

$$u_c = \omega p. \tag{21}$$

$$\omega = \lambda h w_g + \sigma_w w_g h^2 \lambda_h. \tag{22}$$

The corresponding costate equation is the same as equation (14). Again, using equation (21), equation (22) could be rewritten as:

$$w_g = \frac{u_c}{\lambda ph\left(1 + \eta\sigma_w\right)}. \tag{22´}$$

Note that w_g is the marginal health benefit from risk-free medication only.

The optimal condition for self-medication

In this section the optimal condition for self-medication is derived.

Proposition 1: *The (necessary) condition for self-medication is* $v \geq \frac{1-A}{1-q}$ *and the condition for self-medication for all* $v \in (0,1)$ *is* $E\sigma_s \geq \sigma_w$. *On the other hand, self-medication will not occur if* $E\sigma_s < \sigma_w$.

Proof. The proof requires comparing the weighted sum of the marginal health benefit if the individual self-medicates to the benefit without self-medication. Thus,

$$\tilde{s}_y + \tilde{s}_g = \frac{u_c\left(v(q-1)+1\right)}{ph\left(\lambda(1+\eta E\sigma_s)\right)} \geq \frac{u_c}{ph\left(\lambda + \lambda\eta\sigma_w\right)} = w_g . \tag{23}$$

Rearranging the terms in equation (23) gives

$$v \geq \frac{1-A}{1-q}, \tag{24}$$

where $A = \frac{1+\eta E\sigma_s}{1+\eta\sigma_w}$ is some adjusted relative effectiveness of self-medication in reducing the uncertain component of the change in health capital. Moreover, since $q \in (0,1)$, the condition that self-medication will occur for all $v \in (0,1)$ is $A \geq 1$ (i.e. $E\sigma_s \geq \sigma_w$). Thus, if the price of the self-medicated drug is lower than that of the risk-free drug, self-medication will be present if the self-medication, on the average, is more effective (relative to the risk-free medication) in reducing the uncertain component of the dynamics of the health capital. On the other hand, if $q > A$ self-medication will not occur since the perceived probability cannot be greater than 1 (i.e. $v \notin (0,1)$. But $q > A$ implies that $q\left(1+\eta\sigma_w\right) > 1+\eta E\sigma_s$. Since $q \in (0,1)$, it follows that $1+\eta\sigma_w > 1+\eta E\sigma_s$ and $E\sigma_s < \sigma_w$.■

Lemma 1: *The likelihood of self-medicating will increase if the price of the self-medicated drug decreases or if the perception of the effectiveness of self-medication improves, ceteris paribus.*

Note that since $v \geq \frac{1-A}{1-q}$ should hold for an individual to self-medicate, it follows that self-medication will not occur if $v < \frac{1-A}{1-q}$. However, a sufficient reduction in q could change the sign and make self-medication worthwhile. Thus, any policy that increases the cost of accessing professional health care may encourage individuals to switch to self-medication. Furthermore, all other things being equal, an increase in v for example through a public campaign on the effectiveness of a self-medicated drug will encourage individuals who do risk-free medication to take the drug.■

The extent of self-medication

Given that the representative agent self-medicates, this section discusses the extent to which self-medication is done. To facilitate the discussion, some specific forms of the functions in the preceding sections are assumed. Suppose there is diminishing marginal health benefit from increased usage of a prescribed or a self-medicated drug so that $w = w(g) = kg^{\beta}$, where $k > 0$ and $\beta \in (0,1)$. Furthermore, let the health benefit that an individual obtains if she self-medicates be the weighted sum of the benefit from taking the self-medicated and prescribed drugs, with the weights being v. Thus, $s(y,g) = k\left(vy^{\beta+\varepsilon_i} + (1-v)g^{\beta}\right)$ and $E(s) = \tilde{s} = k\left(vy^{\beta+\mu+0.5\sigma_{\varepsilon}^2} + (1-v)g^{\beta}\right)$, where ε is a random variable which takes positive or negative values and has the following moments:

$E(\varepsilon)=\mu$ and $\text{var}(\varepsilon)=\sigma_{\varepsilon}^{2}$[4]. Furthermore, assume the subjective probability of the effectiveness of the self-medicated drug is based on experience so that the relationship between ε_t and v is defined by a cumulative probability density function. Let this function be $\text{Prob}(\varepsilon_t \le \mu+0.5\sigma_{\varepsilon}^{2})=1-v=e^{-\left(\mu+0.5\sigma_{\varepsilon}^{2}\right)}$, which implies that $1-v=e^{-\left(\mu+0.5\sigma_{\varepsilon}^{2}\right)}$ and $\left(\mu+0.5\sigma_{\varepsilon}^{2}\right)=-\ln(1-v)$. Figure 1 depicts the probability density function of the effectiveness of self-medication. Note that $f(\varepsilon_t)$ is the probability density function and the shaded area of the graph defines the perceived subjective probability of non-effectiveness of the self-medicated drug.

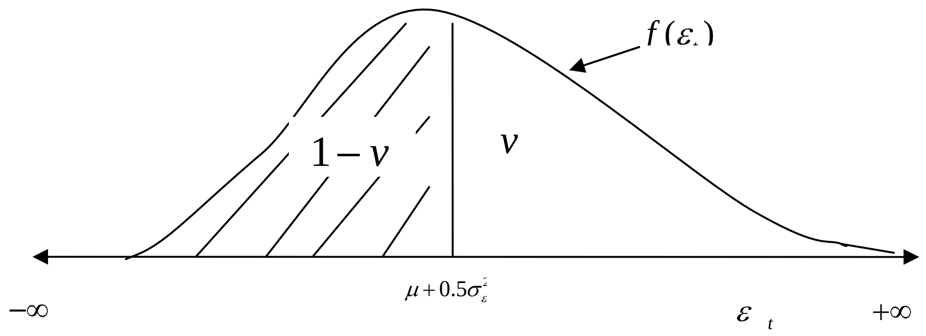

Figure 1*: Probability density function of the effectiveness of self-medication*

Using this definition, dividing equation (11) by (12) and solving for g gives

$$g=\upsilon y^{\sigma}, \tag{25}$$

where $\upsilon=\left(\dfrac{\beta-\ln(1-v)}{q\beta}\right)^{\frac{1}{\beta-1}}$ and $\sigma=\left(\dfrac{\beta-1-\ln(1-v)}{\beta-1}\right)$.

Let $u_c=\theta c^{-1}=\omega p$ so that $c=\dfrac{\theta\omega}{p}$. The budget constraint can therefore be re-specified as

[4] Note that if e is non-stochastic, then $E(e^{\beta+\varepsilon})=e^{\beta+\mu+0.5\sigma_{\varepsilon}^{2}}$ if $E(\varepsilon)=\mu$ and $\text{var}(\varepsilon)=\sigma_{\varepsilon}^{2}$.

$$g = \left(\frac{m - \theta\omega}{1 - v} \right) - \left(\frac{vq}{1 - v} \right) y . \tag{26}$$

From equations (25) and (26), we have

$$\left(\frac{m - \theta\omega}{1 - v} \right) - \left(\frac{vq}{1 - v} \right) y = \upsilon y^{\sigma} . \tag{27}$$

Figure 2 depicts the graph of equations (25) and (26). As can be inferred from the equations and seen from the figure, the model gives a unique equilibrium solution. However, since it is impossible to obtain close-form solutions for y^* and g^* from equation (27) using existing mathematical software, the following section is devoted to some mathematical simulations.

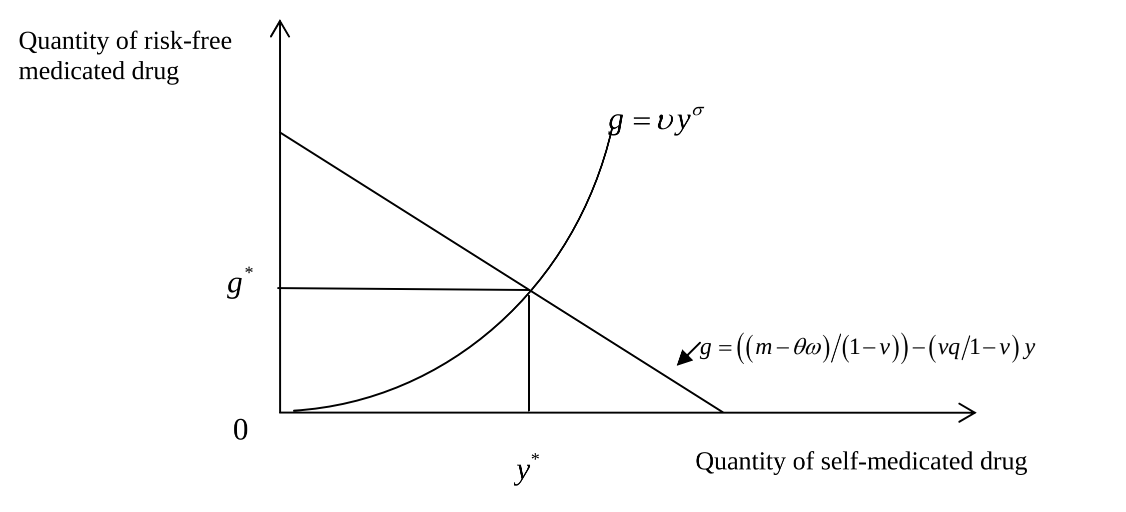

Figure 2: *Equilibrium quantity of risk-free and self medicated drugs*

Numerical simulation of the extent of self-medication

In this section, some parameter values are used to simulate the equilibrium relationship between equations (25) and (26). The values are chosen to satisfy the a priori restriction on the parameters. Thus, $\beta, v, q \in (0,1)$; $m > 0$ and $\theta\omega > 0$. The results presented in Table 1 are based on a simple numerical simulation of equation (27). First, the results show that self-medicated drug obeys the law of demand. From the table, a decrease in the relative price of the self-medicated drug results in an increase in the demand for the self-medicated drug and a decrease in the demand for the risk-free medication (i.e. $\frac{\partial y^*}{\partial q} < 0$ and $\frac{\partial g^*}{\partial q} > 0$). This result can be seen by comparing the figures in the baseline column to that of the fourth column (i.e. for $q \downarrow$). Moreover, the self-medicated drug is a normal good. Thus, a reduction in the disposable income (i.e. $m \downarrow$) decreases the demand for both the self-medicated drug and the risk-free medication (i.e. $\frac{\partial y^*}{\partial m} > 0$ and $\frac{\partial g^*}{\partial m} > 0$).

Second, the results indicate that there is an inverse relationship between the quantities of the self-medicated drug and risk-free medication that is taken on one hand, and the effectiveness of self-medication on the other. From the last column of Table 1, an increase of v from 0.5 to 0.7, all other things being equal, decreased the use of both the self-medicated and risk-free drugs (i.e. $\frac{\partial y^*}{\partial v} < 0$ and $\frac{\partial g^*}{\partial v} < 0$). However, in relative terms, the use of self-medicated drug is intensified several fold (i.e. y^*/g^* increases sharply).

Table 1. Simulated values of real expenditure on self-medicated and risk-free drugs.

Parameters/Variables	*Baseline*	$m\downarrow$	$q\downarrow$	$v\uparrow$
m	10.0	**8.0**	10.0	10.0
$\theta\omega$	0.4	0.4	0.4	0.4
q	0.8	0.8	**0.6**	0.8
v	0.5	0.5	0.5	**0.7**
β	0.3	0.3	0.3	0.3
y^*	**24.2**	**19.2**	**32.2**	**17.1**
g^*	**0.135642**	**0.135335**	**0.090183**	**0.009393**
y^*/g^*	**178.41**	**141.87**	**357.05**	**1820.50**

3. Economic incentive to discourage self-medication

As noted earlier, due to lack of adequate knowledge on some drugs, the proliferation of counterfeit drugs and the sale of prescription-only drugs as OTC drugs, self-medication remains a risky investment in health capital. Moreover, any reduction in health capital may impact negatively on the productive capacities of economies. As a result, policy interventions may be required to discourage self-medication. In this section, an attempt is made at obtaining such a policy instrument. Suppose an individual prefers self-medication to risk-free medication (i.e. $E\sigma_s > \sigma_w$), a subsidy rate of τ that makes equation (24) hold with equality could be defined. Thus, an expression where the individual is indifferent between self-medication and taking risk-free medication is

$$v = \frac{1-A}{1-\frac{q}{1-\tau}}, \text{ where } \quad q \in (0,1), \tag{28}$$

which implies

$$\tau = \frac{v(1-q)+(A-1)}{v+(A-1)}. \tag{29}$$

Proposition 2. *The subsidy must be decreasing in the relative price of the drugs and the perceived probability of effectiveness of self-medication, but increasing in the elasticity of the shadow value of health with respect to the quantity of health capital if* $A > 1$.

Proof. The proof for proposition 2 requires taking partial derivatives of equation (29) with respect to the parameters q, v and η; and looking at the sign of the derivatives. The corresponding results are presented below.

$$\frac{\partial \tau}{\partial q} = \frac{-v}{v + (A-1)} < 0 . \tag{30}$$

$$\frac{\partial \tau}{\partial v} = \frac{-(A-1)q}{\left(v + A - 1\right)^2} < 0 . \tag{31}$$

$$\frac{\partial \tau}{\partial \eta} = \frac{vqA_\eta}{\left(v + A - 1\right)^2} > 0 . \tag{32}$$

Thus, if it becomes more expensive to self-medicate, a lower subsidy rate is necessary to discourage self-medication. Furthermore, if it is less risky to self-medicate, the subsidy must decrease. Moreover, the subsidy must increase if the elasticity of the shadow value of health with respect to the quantity of health capital increases. This is because, if self-medication is more effective in reducing the unpredictable changes in the state of health, then the more an individual values her state of health, the more she self-medicates. A higher subsidy is therefore necessary to discourage such an individual from self-medicating.

Proposition 3. *The subsidy must be decreasing in the relative price of self-medicated and risk-free or prescribed drugs but neither sensitive to a change in perceived probability of effectiveness of the self-medicated drug nor the elasticity of the shadow value of health with respect to the quantity of the health capital if* $A = 1$.

Proof. If $A = 1$, then equation (29) becomes $\tau = 1 - q$. Consequently,

$$\frac{\partial \tau}{\partial q} = -1 < 0, \quad \frac{\partial \tau}{\partial \nu} = 0 \text{ and } \frac{\partial \tau}{\partial \eta} = 0. \tag{33}$$

Thus, if the individual perceives the self-medicated drug on the average, as effective as the risk-free or prescribed drug in reducing the uncertain component of the health capital, then self-medication can only be discouraged if the price differentials between the self-medicated and risk-free or prescribed drugs are eliminated.

4. Conclusions

In developing countries, professional health care is relatively expensive and in some cases completely absent. This situation has created high demand for self-medicated drugs for the treatment of highly prevalent diseases such as malaria. Incorrect diagnosis and dosage, the availability of prescription-only drugs as OTC medication and lax pharmaceutical policies that are leading to proliferation of counterfeit drugs contribute to making self-medication a risky investment in health capital. Although self-medication is common, economic models for such a risky investment are very scarce, with the only exception being the static model of Chang and Trivedi (2003). This paper extends the static model to a stochastic dynamic one, for two situations: where self-medication is present and where it is not present.

The results obtained show that an individual may resort to self-medication if the price of self-medicated drugs decreases relative to that of risk-free medication. Secondly, self-medication could occur if the individual perceives that its effectiveness has increased. Third, self-medication could occur if the elasticity of the shadow value of health with respect to the quantity of health capital increases and if self-medication is relatively more effective in reducing the uncertain component of the dynamics of health capital. Furthermore, self-medication increases if income increases, which makes it a normal good; and it obeys the law of demand. Finally, it has been shown that some optimal subsidy could be used as an economic incentive to discourage self-medication.

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