Motivated health risk denial and the market for preventative health care

Peter Schwardmann †

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Abstract

An individual who feels anxious about contracting a disease may derive comfort from being in denial about her objective risk of infection. Denial, however, comes at the potential cost of distorted decision making. I propose a model of health care investments in which an individual’s belief reflects the optimal trade-off between the psychological benefits and the health costs of denial. The model’s predictions are consistent with evidence that denial is prevalent where there are many constraints to investments in prevention and that, where it arises, it depresses preventative efforts. Unlike other depressants of preventative effort, motivated denial leads to health care demand that is very price-elastic, especially in resource-constrained settings. The model thus helps resolve the empirical puzzle of simultaneously low and price-elastic demand for prevention in developing countries. I also analyze the market for prevention technologies and assess the effectiveness of various policy measures aimed at increasing prevention in the presence of motivated denial.

Keywords: health risk denial, optimal expectations, wishful thinking, preventative health care investments, self-protection, health and economic development.

JEL: D03, I15, I11, I18.

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1 Introduction

I introduce a framework to analyze how anxiety motivates health risk denial and how motivated denial in turn impacts on preventative health care investments. The agent in my model is anxious about contracting a disease and incurring a loss to her physical well-being or material resources in the future. Anxiety is modeled as anticipatory utility, i.e. direct utility from beliefs about future outcomes. The agent may bias her belief about the risk of contracting the disease in order to reduce anxiety, but such denial comes at the potential cost of making overly optimistic decisions in situations in which the individual fails to invest in prevention when the objective risk warrants the investment. Following Brunnermeier and Parker (2005), the agent in my model adopts the belief that is optimal in light of this trade-off.

By nesting a model of motivated belief formation in a model of health care investments, I am able to ask how health risk denial varies with features of the prevention technology and the underlying environment. In a simple and highly stylized framework, I derive closed form solutions for beliefs, the demand for prevention, demand elasticities and the anxiety an individual experiences. Comparative statics exercises that merely involve taking first derivatives are able to match a surprisingly large spectrum of empirical relationships uncovered by the literature on investments in preventative health care.

The model predicts that denial is likely to be especially prevalent and severe if individuals find that their ability to act on accurate information is limited, for example, because prevention technologies are unavailable, expensive or ineffective. If even an unbiased individual is very unlikely to invest in prevention, or if the investment is not expected to yield sufficiently large health benefits, the material or physical costs of denial are low and are likely to be outweighed by the psychological benefits of reduced anxiety. Consistent with this, evidence suggests that HIV/AIDS denial is more prevalent amongst less empowered groups of society and that empowering individuals leads to greater receptiveness towards HIV risk information.

When it occurs, motivated denial depresses the demand for preventative health care, because overly optimistic beliefs cause individuals to place insufficient weight on the adverse prospects that would otherwise incentivize preventative effort. Individuals who engage in motivated denial also exhibit a higher price elasticity of demand for prevention than a realistic economic agent. Demand is more price-elastic because a decrease in the cost of the prevention technology not only increases demand through a standard price effect, but also reduces the degree of optimism, which in turn further increases demand. Lower prices reduce optimism because they increase an individual’s ability to act, thereby making denial more expensive as it would cause the agent to miss out on increasingly profitable preventative health care investments. The price effect on denial and ultimately demand is likely to be particularly strong in resource-constrained settings, where demand is most hampered by motivated cognition in the first place.
A low demand for prevention may have several other underlying causes, like liquidity constraints, exogenous optimism or steep time discounting. All of these other causes, however, imply low elasticities of demand. According to Dupas (2011), a growing body of high-quality evidence from field experiments on health behavior in developing countries suggests that the demand for prevention is low, while price elasticities are high. My model helps resolve this puzzle.

By explicitly modeling the process of belief formation and the decision to exert preventative effort, my framework also allows us to speak about the relationship between an agent’s propensity to feel anxious, or the weight she places on anticipatory feelings, and the anxiety she ultimately experiences. The latter is a function not only of one’s potential for anxiety, but also of the cognitive and investment strategy one chooses to cope with anxiety. Experienced anxiety varies with factors in the environment in a way that is consistent with evidence in Blouin (2014), who finds that an exogenous negative income shock leads to a higher prevalence of HIV because it leads to more risky behavior (i.e. less prevention), while at the same time, people are less worried about HIV (i.e. less anxiety is experienced). The model also provides a theory of why hypochondria, or the excessive worrying about adverse health outcomes, may be a rich country phenomenon.

Section 2 describes the baseline model and mostly focusses on the demand for prevention. The investment cost, or the price of the prevention technology, is assumed to be exogenous. In section 3, I relax this assumption and study how firms who are selling the prevention technology set prices, depending on the market structure. I show that a monopolist reacts strategically to the presence of consumers who may deny their true risk of infection by charging a lower price. Therefore, not only are denialists not money pumps, their behavioral bias actually allows them to decrease the rent they have to transfer to a monopolist who sells them the prevention technology. Moreover, compared to the case of more standard, realistic, consumers, moving from a monopolistic to a competitive market structure leads to a smaller increase in demand and uptake of preventative health care. Motivated denial may thus somewhat surprisingly make the case for competition policy in the market for prevention weaker.

Section 4 presents some policy implications of the motivated denial framework. First, governments seeking to stimulate demand for prevention should be biased towards investing in R&D that seeks to improve the prevention technology’s effectiveness rather than subsidizing consumption. Second, the presence of misguided beliefs does not imply that information campaigns are likely to be effective in changing behavior and does not necessarily provide a rationale for high levels of spending on informing people. In the motivated denial framework, misinformation is motivated and informing individuals of health risks may have little impact on behavior if the underlying incentives to engage in denial are not removed, that is, if individuals are not empowered to take action. Moreover, information campaigns need to be more concerned with persuading (i.e. making it
hard to engage in denial) than just educating people. Third, scaring people may backfire and lead to more denial. The effect of a policy that seeks to increase the salience of future outcomes to increase anxiety crucially depends on whether anxiety only motivates denial or whether it also motivates health care investments. As explained in section 2.5, this in turn depends on how the cost of investing in prevention is processed in an individual’s mental accounts. Fourth, governments or health practitioners that are able to influence an individual’s perception of key variables and that are interested in maximizing physical payoffs, should downplay the cost of prevention and exaggerate its effectiveness as well as the individual’s true risk of infection and cost of being infected. Smaller risks and larger losses should be exaggerated more.

Section 5 concludes and proofs are in the appendix.

Related literature. A large literature, reviewed in Sandroni and Squintani (2004), documents people’s tendency to underestimate health risks. Moreover, many studies link such overoptimism to an underinvestment in precaution and insurance (Sandroni and Squintani, 2004). Kunda (1990) reviews many experimental studies in psychology that suggest that overoptimism is often motivated by people’s desire to feel good about themselves and their future.

For example, in Kunda (1987), female subjects that are heavy coffee drinkers are more likely to reject the validity of a study that links high caffeine consumption to an increased risk of cervical cancer than female subjects that drink coffee less regularly. However, coffee consumption is not correlated with male subjects’ assessment of the study, because, by design, men were not threatened by the health condition in question.

Quattrone and Tversky (1984) provide an example of how the desire to believe something may shape actions: subjects were told that the duration for which they could keep their arm submerged in ice water is indicative of their life expectancy. Those that were told that a long life expectancy corresponded to a long duration kept their arm submerged for substantially longer than those who were told that a short duration was indicative of a long life.

However, while many studies from psychology provide evidence for the existence of motivated denial, or self-deception that is motivated by affective benefits, they usually do not tell us whether beliefs respond to the material or physical costs of denial at the margin. Oster et al. (2013b) study the health beliefs and economic behavior of people at risk of Huntington disease and find evidence for mental processes best described by the optimal expectations paradigm by Brunnermeier and Parker (2005) that also underlies this paper. In their data, individuals’ propensity to engage in denial and thus not get a genetic test for the disease is decreasing in their objective risk of having the disease. Denial is therefore decreasing in the costs associated with biased beliefs, like those stemming from suboptimal savings and retirement decisions. Similarly, Mijović-Prelec and Prelec (2010) find that the prevalence of self-deception in experimental subjects increases with
the desirability of being self-deceived, as measured by the expected profits that accrue to a subject in the state of the world a self-deceiver deems more likely. Eil and Rao (2011), Mobius et al. (2011) and Mayraz (2011) also uncover self-serving overoptimism or biased information processing in the economic decision making of experimental subjects.

The idea that individuals may bias their beliefs in the service of psychological needs forms the basis of the models in Brunnermeier and Parker (2005), Brunnermeier et al. (2007) and Bénabou (2013), who, like me, emphasize an anticipatory utility motive for biased beliefs; the model in Akerlof and Dickens (1982), who stress a related motive of cognitive dissonance reduction; as well as the models in Carrillo and Mariotti (2000) and Bénabou and Tirole (2002), who point to the motivational benefits of strategic ignorance and optimism.

In modeling anxiety as direct utility from beliefs, I follow Caplin and Leahy (2001), Caplin and Eliaz (2003), Kőszegi (2003) and Kőszegi (2006), who, unlike me, do not equip their agents with the ability to choose their beliefs. Kőszegi (2003) studies an anxious individual’s decision to go to the doctor and her choice of the doctor’s quality. In Kőszegi (2006), an informed agent transmits information to a principal with anticipatory utility concerns so as to maximize the principal’s utility. The model bears resemblance to the model in this paper in that agent and principal may be understood as an individual’s current and future selves respectively. However, the future self in this paper, and in optimal expectations models more generally, does not interpret messages from the current self in a Bayesian fashion, but, instead, takes their accuracy and truthfulness for granted. Caplin and Eliaz (2003) analyze theoretically how to compel anxious individuals to get tested for HIV. They do not study denial, i.e. the choice of beliefs, but their general motivation for explicitly modeling anxiety also pertains to this paper:

Psychological realities of this type need no longer be seen as barriers to progress in economic theory. Rather, they are profoundly enriching. The time has come not only to acknowledge their importance, but also to incorporate them into policy analysis.

The implication of exogenously biased beliefs in market settings are investigated in Sandroni and Squintani (2007), Landier and Thesmar (2009), de la Rosa (2011) and Spinnewijn (2013). Bridet and Schwardmann (2014) investigate the impact of motivated belief formation on behalf of borrowers in lending markets.

The psychology of the agent in my model is based on the optimal expectations framework of Brunnermeier and Parker (2005) and some of their predictions readily translate into my setting. For example, Brunnermeier and Parker (2005) argue that optimal expectations imply less risk averse choices, which translates into less preventative effort,¹

¹As Spiegler (2008) points out, the optimal expectations framework need not imply less risk averse choices in the asset market context of Brunnermeier and Parker (2005), if there are more than two assets.
and that they give rise to a general tendency toward optimism, because starting from realistic beliefs, the material costs of optimism are of second order while the psychological benefits are generally of first order.

But by imposing the structure of a preventative health care investment problem on the agent’s decision, I am also able to go beyond what the more general model in Brunnermeier and Parker (2005) tells us. I am able to ask how the material costs and psychological benefits of optimism vary with features of the prevention technology and the environment. For example, I show that, compared to other features such as price, the technology’s effectiveness has an especially large impact on denial because a lower effectiveness decreases the material cost and increases the psychological benefit of denial. To my knowledge, this is also the first paper to study the link between optimal expectations or motivated denial and demand elasticities and to analyze an explicit measure of the level of anxiety an individual experiences. Finally, I study the strategic interaction between firms and denialists and derive novel policy implications.

2 The model

2.1 The set-up

At \( t = 1 \) an agent observes her true risk of infection \( \theta \) and chooses her belief \( \hat{\theta} \) so as to maximize the weighted sum of her expected physical and anticipatory payoffs

\[
E_1 \left[ U (\theta, x(\hat{\theta})) \right] + s E_1 \left[ U (\hat{\theta}, x(\hat{\theta})) \right]
\]

where \( s \) is the weight the agent places on anticipatory utility and captures her propensity to feel anxious or the salience of future outcomes. The agent’s physical payoffs depend on her actual risk as well as her beliefs, in so far as her beliefs impact on \( x \), the decision to invest in prevention. Anticipatory payoffs only depend on beliefs, not reality, and are what an agent engaging in denial seeks to inflate.

At \( t = 2 \) an individual decides whether to invest in prevention, based on her beliefs. Because the agent at \( t = 1 \) faces uncertainty over the cost of investing at \( t = 2 \), denial or biased beliefs always entail at least a small risk of making a suboptimal investment decision.

Anticipatory utility from the agent’s possibly biased \( t = 2 \) expectation of final payoffs is realized at \( t = 2 \), while material payoffs, which are evaluated at the true risk of infection, are realized at \( t = 3 \). The timing of the agent’s choices and payoffs is summarized in Figure 1.

of different riskiness that the agent may choose. In the health domain, and in the absence of multiple prevention technologies, however, the predicted increase in risk lovingness is likely to be more robust.
- Observes true risk $\theta \in (0, 1)$
- Cost $c$ is realized
- Chooses belief $\tilde{\theta} \in (0, 1)$
- Invests $x$ based on belief $\tilde{\theta}$
- Obtains material payoffs
- Obtains anticipatory utility

Figure 1 Timing of agent’s actions and the realization of payoffs

2.1.1 The investment decision at $t=2$

At $t = 2$, the risk-neutral agent decides whether or not to invest in preventative health care after observing a realization of the investment cost, $c$, with p.d.f. $f(c)$ and c.d.f. $F(c)$. I assume that $c$ is uniformly distributed on the support $[0, \bar{c}]$.\(^2\)

A uniformly distributed random cost allows me to derive a closed form solution of optimal beliefs and yields smooth expected demand for prevention, which in turn allows me to derive demand elasticities. The random variable $c$ may capture a pecuniary cost; the opportunity cost of forgoing the consumption of other goods, and thus, an individual’s income; the discomfort associated with a medical procedure; the difficulty of reaching a health facility; or the cost of exerting the willpower required to make the investment (e.g. when deciding to abstain from risky sex).

If the agent does not contract the disease she obtains utility $V$. If she contracts the disease, she incurs a loss $L$ and her utility is thus $V - L$. In addition to her material or physical payoffs at $t = 3$, the agent derives anticipatory utility at $t = 2$, which she weights by $s$.\(^3\) I assume that $s < 1$, so that the agent never places more weight on her anticipatory feelings than on the actual outcome.

Whether an agent can avoid contracting the disease by investing in prevention depends on the effectiveness of the prevention technology $\alpha \in [0, 1]$, and on the agent’s risk of infection $\theta \in [0, 1]$. If she invests, an agent is protected from infection with probability $\alpha$, while with probability $1 - \alpha$, her prevention technology fails her. In situations in which the prevention technology fails or the agent never invested in prevention in the first place, she gets infected with probability $\theta$.

The agent bases her $t = 2$ investment decision on a subjective belief regarding her risk of infection, which is denoted by $\hat{\theta}$ and which need not correspond to the true risk of infection, $\theta$. At $t = 2$ the agent’s beliefs are already chosen and, unlike at $t = 1$, both material and anticipatory payoffs are thus evaluated at $\hat{\theta}$. The agent’s binary investment decision is denoted by $x \in \{0, 1\}$, where $x = 1$ means making the investment. Ignoring time discounting, the expected utility at $t = 2$ as a function of the agent’s investment

\(^2\)The expected investment cost $\bar{c}/2$ will often feature in the analysis that follows. In the case of a uniform distribution with support $[0, \bar{c}]$, $\bar{c}/2$ is a measure of the mean as well as the upper bound and the variance of the distribution. However, all major results go through if we used a uniform distribution whose mean is not also half of its range.

\(^3\)An anxious agent may be modeled as experiencing losses in anticipatory utility from her expectation of material losses at $t = 3$ without experiencing gains in anticipatory utility from future material gains. All of the model’s conclusions are robust to this alternative assumption on utility from beliefs.
decision $x$ is given by

\[
(1 + s) \mathbb{E}_2 \left[ U \left( \tilde{\theta}, x \right) \right] = (1 + s)[x (\alpha V + (1 - \alpha)(1 - \tilde{\theta})V + \hat{\theta}(V - L)) - c]
\]

\[
+ (1 - x)((1 - \tilde{\theta})V + \hat{\theta}(V - L))]
\]

(1)

where the first line captures the agent’s expected utility from investing and the second line her expected utility from not investing. If she invests and the prevention technology works, she obtains $V$. With probability $1 - \alpha$ the technology fails, in which case she expects to remain healthy and obtain $V$ with probability $1 - \tilde{\theta}$ and to get infected and obtain $V - L$ with probability $\tilde{\theta}$. Regardless of the outcome, if she invests, the agent has to pay the investment cost $c$. At $t = 2$ the agent’s expectation of her $t = 3$ material payoffs and her anticipatory utility are based on the same, possibly biased, belief $\tilde{\theta}$. They are thus equal, and while $\mathbb{E}_2 \left[ U \left( \tilde{\theta}, x \right) \right]$ is premultiplied by $1 + s$, the parameter $s$ will not impact on the agent’s $t = 2$ investment decision.

The agent invests if $\left[ U_2 \left( \tilde{\theta}, x = 1 \right) \right] > \mathbb{E}_2 \left[ U \left( \tilde{\theta}, x = 0 \right) \right]$. This is the case whenever

\[
\alpha \tilde{\theta} L \geq c
\]

(2)

The agent’s investment decision is in line with the four core constructs in the health belief model (Janz and Becker, 1984), the tool that is most widely used by psychologists to understand changes in health behavior: investment or behavioral change is more likely when the the perceived susceptibility to a health problem (i.e. $\tilde{\theta}$) is high, when the perceived severity of a condition (i.e. $L$) is high, when the perceived benefits or the efficacy of engaging in a health-promoting behavior (i.e. $\alpha$) is high, and when perceived barriers to taking action (i.e. $c$) are low. In my model, only the perceived susceptibility may differ from reality, but the model’s insights readily translate to cases where other variables are subject to misperception or even directed belief manipulation.

### 2.1.2 Belief choice at $t=1$

At $t = 1$, the agent learns her true risk $\theta \in [0, 1]$ and then chooses her belief $\tilde{\theta} \in [0, 1]$ under consideration of the investment decision it will induce. Her $t = 1$ expected utility
is

\[ E_1 \left[ U \left( \theta, \hat{\theta} \right) \right] + s E_1 \left[ U \left( \hat{\theta}, \hat{\theta} \right) \right] = \]

\[ \int_0^{\alpha \hat{\theta} L} \alpha V + (1 - \alpha)[(1 - \theta)V + \theta(V - L)] - c \ dF(c) \]

\[ + \int_{\alpha \hat{\theta} L}^{\theta} (1 - \theta)V + \theta(V - L) \ dF(c) \]

\[ + s \int_0^{\alpha \hat{\theta} L} \alpha V + (1 - \alpha)[(1 - \tilde{\theta})V + \tilde{\theta}(V - L)] - c \ dF(c) \]

\[ + s \int_{\alpha \hat{\theta} L}^{\theta} (1 - \tilde{\theta})V + \tilde{\theta}(V - L) \ dF(c) \]

(3)

First note that \( c \) is random from the perspective of \( t = 1 \) and the agent therefore forms an expectation over the realization of \( c \) at \( t = 2 \) and over whether this realization induces investment. When the agent engages in denial she knows that she will only invest if the realized cost turns out to be smaller than the perceived benefits on preventative effort \( \alpha \hat{\theta} L \).

The second and fourth line of (3) express respectively the material and psychological payoffs from investing in prevention weighted by the probability that investment occurs. Lines three and five express the payoffs for cost realizations that induce the agent not to invest in prevention. The agent derives utility from actual \( t = 3 \) outcomes, which are given in lines 2 and 3, and from her expectation at \( t = 2 \) over outcomes at \( t = 3 \), which are given in lines 4 and 5 and which are multiplied by \( s \), the weight the agent places on anticipatory feelings.

The agent at \( t = 1 \) knows that her risk is \( \theta \) and that her actual \( t = 3 \) health will be shaped by her true risk. Accordingly, conditional on investing or not investing, the material payoffs do not depend on whether the agent engages in denial or not. Denial does, however, affect the agent’s \( t = 2 \) expectation. Therefore, the anticipatory utility she receives conditional on her investment decision is greater if she maintains a rosy view of the risks she faces, i.e. if \( \tilde{\theta} < \theta \). Gains in anticipatory utility, however, come at the potential cost of impaired decision making when an optimistic agent should invest, in light of her objective risks, but fails to do so. This cost is reflected in the fact that the upper bounds of the integrals in lines 2 and 4 and the lower bound of the integrals in lines 3 and 5 and therefore her probability of investing are lower for lower \( \tilde{\theta} \).

The \( t = 1 \) expected utility in (3) embodies the following assumption.

**Assumption 1.** \( \alpha \hat{\theta} L < \tilde{c} \)

I therefore consider a world in which, at \( t = 2 \), it is sometimes the case that \( \alpha \hat{\theta} L < c \), so that even a realistic agent does not always find it profitable to invest in prevention.\(^4\)

\(^4\)This assumption is not crucial for the workings of the model’s central mechanisms, it only simplifies their exposition.
2.2 Optimal beliefs

There is potentially another reason the poor may hold on to beliefs that might seem indefensible: When there is little else they can do, hope becomes essential. [Banerjee and Duflo, 2011]

The optimal belief \( \tilde{\theta}^* \) the agent ultimately adopts, is the belief that maximizes (3), her \( t = 1 \) expected utility

\[
\tilde{\theta}^* = \arg \max_{\tilde{\theta}} E_1 \left[ U(\theta, \tilde{\theta}) \right] + sE_1 \left[ U(\tilde{\theta}, \tilde{\theta}) \right]
\]

if the \( \tilde{\theta} \) that maximizes (3) is greater than zero. If the \( \tilde{\theta} \) that maximizes (3) is smaller than zero, then \( \tilde{\theta}^* = 0 \), because negative probabilities make no sense.

**Proposition 1.** The optimal belief is given by

\[
\tilde{\theta}^* = \max \left[ \frac{\theta}{1 - s} - \frac{s\bar{c}}{(1 - s)\alpha^2 L}, 0 \right]
\]

In the case of \( s = 0 \), when the agent never feels anxious and thus resembles the rational agent of more standard economic models, the optimal belief is realism, i.e. \( \tilde{\theta}^* = \theta \). The model therefore nests a more standard model as a special case. When \( s > 0 \), however, the agent always exhibits at least some optimism. To see why this is the case it is useful to consider the marginal material cost of decreasing one’s subjective evaluation of risk, i.e. of becoming more optimistic. It corresponds to the first derivative with respect to \( \tilde{\theta} \) of lines 2 and 3 in (3)

\[
\frac{\partial E_1[U(\theta, \tilde{\theta})]}{\partial \tilde{\theta}} = \frac{\alpha L}{\bar{c}} \left( \frac{\alpha L}{P_{r'(x=1)}} - \frac{1}{2} \frac{\alpha L}{NB(x=1)} \right) - \frac{\alpha \tilde{\theta} L}{\bar{c}} \left( \frac{1}{2} \frac{\alpha L}{NB'(x=1)} \right)
\]

where \( P_{r'(x=1)} \) is the ex ante probability of investing and \( NB'(x=1) \) the expected material benefit of investing net of the expected investment cost. For a decrease in \( \tilde{\theta} \), the first term of (4) thus captures the loss the agent suffers from forgoing profitable investments. The second term represents a gain and captures the fact that, conditional on having invested, the average investment a more optimistic agent makes is less costly. When \( \tilde{\theta} = \theta \), a slight decrease in the subjective risk does not carry a material cost, i.e. \( \frac{\partial E_1[U(\theta, \tilde{\theta})]}{\partial \tilde{\theta}} \Big|_{\theta = \tilde{\theta}} = 0 \). The belief \( \tilde{\theta} = \theta \) is thus never optimal for an individual who obtains even a small psychological benefit from being optimistic.\(^5\)

The marginal material cost of further decreasing the agent’s belief is increasing in optimism. This convexity of equation (4) on the interval \( \tilde{\theta} \in [0, \theta] \) sheds light on why

\(^5\)Note that the result that \( s > 0 \) always implies some optimism need not hold for a different cost distribution and if we relax the assumption that there is no cognitive cost of engaging in denial.
the agent’s objective function (3) is concave and we are therefore at an interior solution provided that $\alpha^2 \theta L > se$. The lower $\bar{\theta}$, the higher the expected net benefit $NB(x = 1)$ the agent forgoes by further reducing her investment probability, because she fails to make increasingly profitable investments. Furthermore, the lower $\bar{\theta}$, the lower $Pr(x = 1)$ the likelihood that the marginal cost savings on the infra marginal investment, as captured by $NB'(x = 1)$, are realized.

Note that psychological benefits, i.e. lines 4 and 5 in (3), are also increasing in optimism at an increasing rate. But the assumption that $s < 1$ entails that the marginal material costs increase faster than marginal psychological payoffs decrease as the agent becomes more and more optimistic. The resulting decreasing returns to optimism imply concavity of the objective function.

The closed form solution of optimal beliefs allows me to derive comparative statics and ask how denial is influenced by factors in the environment. It is instructive to present these comparative statics in terms of optimism rather than subjective risk.

**Definition 1.** Optimism is the difference between an agent’s true and subjective risk: $\tilde{\Delta} = \theta - \bar{\theta}$.

The variable $\tilde{\Delta}$ is decreasing in subjective risk, and a more optimistic individual will therefore have a higher $\tilde{\Delta}$. $\tilde{\Delta}$ reflects a pure bias, while $\bar{\theta}$ is at least partially based on the real risk of infection.

**Corollary 1.** The agent’s optimal belief responds to shifts in parameters as follows: Optimism $\tilde{\Delta}$ is

i) weakly increasing in the expected investment cost $\bar{c}$

ii) weakly decreasing in the effectiveness of the prevention technology $\alpha$,

iii) weakly decreasing in the potential loss $L$,

iv) weakly decreasing in the true risk of infection $\theta$ if $\bar{\theta} > 0$,

v) and weakly increasing in an individual’s innate anxiety $s$.

The intuition for result i) is simple. When the agent at $t = 1$ expects the investment cost to be high, it is less likely that she will end up making the preventative health care investment at $t = 2$. Engaging in denial will thus bring about a suboptimal investment decision less often. At the same time, because a high $\bar{c}$ implies the individual goes unprotected relatively often, the psychological benefits of underestimating the likelihood of infection are larger.

Result ii) follows a similar logic. An ineffective prevention technology entails that investments in prevention occur relatively rarely and the likelihood of denial causing a very costly bad decision is therefore reduced. Furthermore, a low $\alpha$ implies that even if an individual invests in health, she may contract the disease with a high likelihood. This further raises the psychological benefits of denial.
According to results i) and ii), optimism or denial is decreasing in an individual’s ability to act on accurate information. We therefore expect denial to be more prevalent amongst less empowered groups, e.g. women in traditional societies, and amongst those who do not have access to cost-effective, state-off-the-art health care. Furthermore, it is not surprising that in developed countries, arguably the highest prevalence of misguided patient beliefs and quacks (who sell dreams, i.e. facilitate denial) is found for health conditions that do not allow for effective preventative measures or cures. Banerjee and Duflo (2011) cite the example of back pain.

Because \( s < 1 \) and hence, an individual cares more about physical outcomes than anticipatory feelings, a higher loss \( L \) and a higher objective risk \( \theta \) discipline the individual’s desire to engage in denial. While both the material costs and the psychological benefits from becoming more optimistic are increasing in \( \theta \) and \( L \), \( s < 1 \) implies that more weight is put on the costs.

Result v) makes the intuitive point that denial increases in the weight an individual puts on anticipatory feelings \( s \). Note, however, that v) need not hold when anxiety not only drives optimism, but also directly impacts upon an individual’s propensity to invest in prevention. This scenario is explored in section 2.5.

**The denial of HIV risks may be caused by an inability to act.** In the context of a large generalized HIV epidemic, being in denial about some of the risks and costs associated with HIV/AIDS may constitute an important psychological coping mechanism and help reduce anxiety. The model emphasizes that such denial may come at the cost of impaired sexual decision making, since an overly optimistic individual may fail to protect herself when the risk of infection does in fact warrant taking protective measures. This cost, however, may be low for groups who lack autonomy in sexual decision making. A lack of empowerment on behalf of women in many African countries, in particular, may therefore help explain gender differences in HIV knowledge and risk attitudes.

In terms of the model, a lack of empowerment or autonomy in sexual decision making may be reflected in a high cost of protecting oneself, i.e. a high \( \bar{c} \). Alternatively, the risk of potentially being undermined by one’s partner may be reflected in a low \( \alpha \). A low \( \alpha \) may also represent situations in which a woman may protect herself in all of her voluntary sexual encounters, but cannot avoid the threat of being raped. That this threat is real and prevalent in some contexts is reflected in South African estimates that, based on interviews with women attending antenatal clinics, place the prevalence of physical/sexual partner violence as high as 55.5% (Dunkle et al., 2004).

Green et al. (2006) find that the social, economic and legal empowerment of women played a crucial role in Uganda’s strategy to combat HIV/AIDS, which is widely considered to be one of the few successful HIV prevention campaigns in Africa. In particular, they highlight the role of giving women more political voice, the strengthening of rape and defilement laws and the allocation of property rights to women.
In a South African sample, 10.5 percent of African women compared to 1.71 percent of African men believe that “HIV is harmless and does not cause AIDS” (Grebe and Nattrass, 2011). Men, on the other hand, are more likely than women to agree with the statement that “AIDS was created by American scientists”. The stark difference in the distribution of AIDS denialist beliefs compared to AIDS conspiracy theorist beliefs points to motivated beliefs resulting from low empowerment, since other variables such as educational attainment should have a negative effect on both kinds of beliefs. The fact that female empowerment is low in South Africa is reflected in the high incidence of partner violence against women. This has implications for sexual outcomes, as young men who perpetrate partner violence engage in significantly higher levels of HIV risk behavior than non-perpetrators (Dunkle et al., 2006) and women with low relationship control are 2.1 times more likely to use condoms inconsistently (Pettifor et al., 2004).

Education is likely to play an important role in empowering women. In a field experiment in Kenya, Duflo et al. (2006) find that reducing the cost of education leads more girls to be “confident that they can say no if their partner wants to have sex” and to realize that “when one has HIV, one eventually dies”. Training teachers to teach the national AIDS curriculum or encouraging students to discuss condom use had no effect on these perceptions, which indicates that it may be the empowerment that is associated with education rather than the provision of information that shifts attitudes.

In a Ugandan sample, De Walque (2007) shows that the reduction in seroconversion following a HIV information campaign is increasing in educational attainment. This result is driven exclusively by women being more receptive to HIV information when they are more educated. Since it is plausible that empowerment through education is greater for women than for men, but somewhat less plausible that education affects men and women’s information processing or cognitive abilities differently, this evidence lends further support to the model’s predictions in the realm of HIV/AIDS.

It is possible that the mechanisms highlighted above contribute to a gender gap in HIV knowledge that is observable in country-level data. According to UNAIDS/WHO (2005), young men in a sample drawn from 35 countries in sub-Saharan were 20% more likely to have correct knowledge about HIV than young women.

Figure 2a exhibits the positive relationship (significant at the 5 percent level) between the gender gap in HIV knowledge and the social institutions and gender index (SIGI) for a sample of 38 countries. The HIV knowledge variable measures the percentage of young people aged 15 to 24 who both correctly identify ways of preventing the sexual transmission of HIV and reject major misconceptions about HIV transmission. The SIGI measures social and institutional inputs to gender inequality such as laws prohibiting

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6Estimates derived from household surveys (DHS, MICS) are presented here, as compiled and reported by UNAIDS in the 2008 Report on the Global AIDS epidemics, Annex 2 UNAIDS (2008).
and punishing violence against women, women’s ownership rights, dress codes in public, the acceptability of polygamy and genital mutilation, and freedom of movement. The index takes a higher value for greater gender inequality.

It may be argued that gender inequality impacts on HIV knowledge exclusively through differences in education. Figure 2b shows that a positive relationship (significant at the 10 percent level) between gender differences in HIV knowledge and female empowerment persists once we make the gender gap in HIV knowledge conditional on a country’s gender gap in literacy rates. The notion that low female autonomy incentivizes denial is one candidate explanation for this finding. Another explanation may be that learning information pertaining to HIV requires freedom of movement and interactions with peers, which are undermined by social norms that discriminate against women.

2.3 The demand for preventative health care

2.3.1 Motivated denial depresses demand

It is important to understand how the beliefs the agent adopts at \( t = 1 \) impact on her investment decision at \( t = 2 \). Let us define the demand for preventative health care as the ex ante probability that an individual invests

\[
D^d \equiv Pr(x = 1|\tilde{\theta}^*) = \int_0^{\alpha\tilde{\theta}^*} f(c) \ dc
\]

\[
= \begin{cases} 
\frac{\alpha\theta L}{(1-s)c} - \frac{s}{(1-s)c} & \text{if } \alpha^2\theta L > s\bar{c} \\
0 & \text{otherwise}
\end{cases}
\]  

(5)

where the superscript \( d \) denotes the denialist’s demand. \( D^d \) is also the aggregate demand in a population with random investment costs, but homogenous cost distribu-
tions \( f(c) \). By comparison, the ex ante probability that a realist, i.e. a more standard economic agent, invests is given by

\[
D^r \equiv Pr(x = 1 | \theta) = \int_0^{\alpha \theta L} f(c) \, dc
\]

(6)

\[
= \frac{\alpha \theta L}{\bar{c}}
\]

Definitions (5) and (6), together with the fact that \( \tilde{\theta}^* < \theta \), imply the following proposition.

**Proposition 2.** The motivated denial of health risks depresses the demand for preventative health care, i.e. \( D^d < D^r \). The difference in a realist’s and a denialist’s demand is greater,

i) the greater the expected cost of prevention \( \bar{c} \), i.e. \( \frac{\partial (D^r - D^d)}{\partial \bar{c}} > 0 \),

ii) the lower the effectiveness of the prevention technology \( \alpha \), i.e. \( \frac{\partial (D^r - D^d)}{\partial \alpha} < 0 \),

iii) and the lower the potential loss \( L \), i.e. \( \frac{\partial (D^r - D^d)}{\partial L} < 0 \).

A researcher who observes preventative efforts through the lens of a standard model and without observing beliefs may thus find that the demand for prevention is too low in light of the available prevention technology and the benefits of prevention. Furthermore, the demand for prevention will seem especially low in poor settings that are characterized by high \( \bar{c} \), low \( \alpha \) and low \( L \). If low demand coincides with an observation of misinformation or optimism, information campaigns may appear to be the appropriate policy intervention. However, the model highlights that both biased perceptions and underinvestment in health care may be driven by the underlying environment and technology, which would need to be changed first for information campaigns to be fruitful.

**Individuals in developing countries spend only a small fraction of their budgets on preventative health care.** In a survey of the empirical literature on health behavior in developing countries, Dupas (2011) finds that two empirical regularities deserve the “stylized fact” label. First, curative health expenditures consume a large part of people’s budget, e.g. as much as 10 percent in urban India (Dupas, 2011) and 8 percent in rural Kenya (Dupas and Robinson, 2009). These figures are more than twice as high as the share of curative health expenditures in the developed world. Second, given these large investments in treatment and the high incidence of mortality from preventable diseases, investments in prevention are very low in the developing world.

Proposition 2 demonstrates that motivated health risk denial provides a possible explanation for why individuals may invest so little in preventative health care even when its private benefits appear to outweigh its cost, especially in poor countries. The high opportunity cost of investing in health that results from a low income may cause denial. In addition to a low income, a high general disease burden, as reflected in a low
or the poor quality of and limited faith in available health care, as reflected in a low 
\( \alpha \), may make the occurrence of denial more likely in developing countries.

Note that the mechanism I describe is likely to be far more pertinent to investment 
in prevention than to investment in treatment and, hence, is consistent with the fact 
that investment in treatment is relatively high in developing countries. Treatment, in 
many cases, seeks to remedy discomfort that is currently felt and may thus be less 
susceptible to wishful thinking. Furthermore, the pain brought about by an ailment may 
well diminish the marginal utility from consuming other goods, and the opportunity cost 
of forgone consumption of other goods may thus be less of an impediment to investment 
in treatment than it is an impediment to investment in prevention.

2.3.2 Motivated denial of health risks leads to high elasticities of demand

The phenomenon of low expenditure in preventative health care admits other expla-
nations. These include exogenously biased beliefs that are not the function of motivated 
denial but, for example, the function of a lack of access to information; impatience or 
steep discounting of future payoffs; and liquidity constraints due to imperfect financial 
markets. We have seen that the demand depressing effects of motivated denial are likely 
to be particularly severe in poor settings, a prediction that matches empirical evidence. 
However, liquidity constraints are clearly also more likely to be a problem in poor set-
tings. Likewise, exogenously biased beliefs may be the result of low levels of education. 
Finally, the poor may be more impatient, because there are larger demands on their 
scarce willpower.

To the extent that elicited beliefs capture the variable \( \tilde{\theta} \),\(^8\) the coexistence of low 
demand and biased beliefs may point to the presence of motivated denial, but it does 
not allow us to reject the hypothesis that exogenous optimism is at work. Fortunately, 
elasticities of demand can help identify the drivers of low demand.

I denote the (exogenous) optimist by superscript \( o \). She is characterized by belief 
\( \theta^o < \theta \) with \( \frac{\partial \theta^o}{\partial z} = 0 \) for all \( z \in \{ \bar{c}, L, \alpha, \theta \} \). Her demand for health care is given by 

\[
D^o = \int_0^{\alpha \theta^o L} f(c) \, dc
\]

An impatient individual discounts \( t = 3 \) health outcomes when she decides whether or 
not to invest in health care at \( t = 2 \). She has a discount rate \( \beta < 1 \) and invests in

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\(^8\)\( \tilde{\theta} \) reflects an individual’s awareness of health risks in the situation in which she makes health-
relevant decisions, which may not necessarily coincide with what she answers when prompted by a 
survey question. I, for example, would respond fairly accurately to a survey question about the dangers 
of high cholesterol. Yet, although I do in fact have high levels of cholesterol, my diet rarely reflects 
preventative efforts, because I manage to push uncomfortable thoughts about heart disease out of my 
awareness at most times.
prevention whenever $\beta \alpha \theta L > c$. Her ex ante demand is given by

$$D^\beta = \int_0^{\beta \alpha \theta L} f(c) \, dc$$

Finally, a liquidity constraint individual can only invest in prevention for cost realizations such that $c < m$ and $m$ is so small that she cannot always make worthwhile investments, i.e., $m < \alpha \theta L$. Her demand is

$$D^m = \int_0^m f(c) \, dc$$

Elasticities of demand in a variable $z$ are defined as follows

$$\eta^r_z = \frac{dD^r}{dz} \frac{z}{D^r}, \quad \eta^d_z = \frac{dD^d}{dz} \frac{z}{D^d}, \quad \eta^o_z = \frac{dD^o}{dz} \frac{z}{D^o}, \quad \eta^\beta_z = \frac{dD^\beta}{dz} \frac{z}{D^\beta}, \quad \eta^m_z = \frac{dD^m}{dz} \frac{z}{D^m}$$

The following proposition highlights a difference between the elasticity of demand of an individual who engages in motivated denial and that of the other agents I have introduced.

**Proposition 3.** Suppose that $\alpha^2 \theta L > s\bar{c}$, so that an individual who engages in denial sometimes invests in prevention. Then the demand for preventative health care of someone who engages in motivated denial is more sensitive to changes in the environment than the demand of a realistic individual, as well as the demand of an exogenously optimistic, impatient or a liquidity constrained individual. Specifically,

i) $\eta^d_\alpha > \eta^r_\alpha = \eta^\beta_\alpha = \eta^o_\alpha > \eta^m_\alpha$;

ii) $\eta^d_\theta > \eta^r_\theta = \eta^\beta_\theta = \eta^o_\theta > \eta^m_\theta$;

iii) $\eta^d_\theta > \eta^r_\theta = \eta^\beta_\theta = \eta^o_\theta > \eta^m_\theta$;

iv) and $\eta^d_\bar{c} < \eta^r_\bar{c} = \eta^\beta_\bar{c} = \eta^o_\bar{c} = \eta^m_\bar{c}$.

We thus have that the denialist’s elasticity of demand is more positive for positive shifts in demand and more negative for negative shifts in demand than the elasticity of a realist. To understand the intuition behind the denialist’s more extreme elasticities, note that a change in the expected investment cost $\bar{c}/2$, for example, impacts on demand in two ways: first, holding beliefs constant, a cost reduction leads to more investment through a standard price effect; second, demand is further increased because, by corollary 1, beliefs become more realistic.

Proposition 3 implies that elasticities of demand may be a good metric to distinguish motivated beliefs from other depressants of demand. It also implies that the returns to subsidies and improvements in prevention technology may be underestimated through the lens of another model. That this is particularly true in poor settings is made explicit in the following corollary.\(^9\)

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\(^9\)It can also be shown that other impediments to demand, like steep discounting or liquidity con-
Corollary 2. The difference between a denialist’s and a realist’s price elasticity of demand is larger when \( \bar{c} \) is high, i.e. \( \frac{\partial(\eta_d - \eta_r)}{\partial \bar{c}} < 0 \).

**Price effects on preventative health investments are typically large.** Ashraf et al. (2010) find that, in a Sambian sample, the take up of a water treatment product increases from 50 to 80 percent as the price decreases from U$ 0.25 to U$ 0.10. Cohen and Dupas (2010) and Kremer and Miguel (2007) find large price effects on the take up of bed nets and deworming medication respectively. According to Dupas (2011), high price elasticities of the demand for prevention are the norm rather than the exception in developing countries, which is particularly surprising in light of the low demand. But while large price effects may be surprising if we expect low demand for prevention to be the result of deeply held beliefs or misinformation, for example, we have seen they are consistent with motivated denial.

The motivated denial framework also implies that information provision will interact with interventions that enhance individuals’ ability to act to produce strong effects on preventative behavior. In line with this reasoning, Ashraf et al. (2011) find that providing additional information about a health product significantly increases the impact of a price subsidy on take-up.

### 2.4 Experienced anxiety

Many surveys ask respondents how worried they are about contracting a certain disease. The answer to such questions does not only depend on an individual’s propensity to feel anxious, i.e. \( s \) in my model, but also on whether she invests in prevention and whether she is engaging in denial. Lazarus (2006) cautions scholars of emotion and stress to appreciate that “separating emotion from coping does a disservice to the integrity and complexity of the emotion process, which at any turn considers how we might cope” (p. 37). My model imposes some structure on how we think about the interrelationship between anxiety, cognitive coping, i.e. denial, and behavioral coping, i.e. investing in prevention. Let \( \mathcal{A} \) denote the average or expected level of anxiety an individual experiences. It is given by

\[
\mathcal{A} = s \left[ \int_0^{\alpha \theta L} (1 - \alpha) \tilde{\theta} L + c \ dF(c) + \int_{\alpha \theta L}^{\bar{c}} \tilde{\theta} L \ dF(c) \right] \tag{7}
\]

if \( \alpha^2 \theta L > s \bar{c} \). If \( \alpha^2 \theta L < s \bar{c} \) then \( \tilde{\theta} = 0 \) and the agent is not anxious at all. The first term of \( \mathcal{A} \) is the expected anxiety the agent feels from anticipating being infected although she

\[^{10}\text{Note that } \eta_d^{\bar{c}} - \eta_r^{\bar{c}} \text{ is a negative number and a larger difference thus corresponds to a more negative number.}\]
invested in prevention, while the second term is the expected anxiety from not investing. A higher level of $A$ is synonymous with elevated anxiety, dread or worry and hence, lower utility. As the expected investment cost increases, investment in prevention decreases, which increases the threat of infection and experienced anxiety. At the same time, an increase in $\bar{c}/2$ increases denial, which reduces anxiety. Proposition 4 states the net effect of a change in the investment cost on anxiety.

**Proposition 4.** Experienced anxiety $A$ is weakly decreasing in the expected investment cost $\bar{c}/2$, i.e. $\frac{\partial A}{\partial \bar{c}} \leq 0$.

Recall that a high $\bar{c}/2$ may capture a low income, a high opportunity cost of investment, or low levels of willpower. Proposition 4 thus tells us that in very poor settings, where $\bar{c}/2$ is high, a further drop in income or an increase in the price of prevention leads to a reduction in anxiety.

Proposition 4 also suggests a reason why elevated levels of experienced anxiety, and in its most extreme form, hypochondria, might be a rich country phenomenon: it is in these settings where the material payoffs warrant remaining realistic, even if this comes at the cost of worrying.

A drop in income can lead to increases in HIV infection and decreases in experienced anxiety. Blouin (2014) uses the exogenous income shock of the 2007 famine in Malawi to identify a significant positive effect of poverty on HIV prevalence. He finds that the drop in income made individuals less diligent in avoiding risky behaviour in current relationships and that while HIV increased in affected areas, people actually worried less about the actual correlation. In Malawi’s poor rural setting, this is exactly what the model predicts. As a lower income increases the need for transactional sex, depletes willpower and, potentially, diminishes the value of an uninfected life, denial increases, the demand for safe sex decreases and, by proposition 4, experienced anxiety decreases.

### 2.5 Anxiety-driven health investments

In the baseline model, I assume that the cost $c$ an individual incurs in making a health investment is subtracted from her $t = 3$ utility, in addition to any loss she may incur. Investing in health was therefore not a direct means to reduce anxiety, because it subtracted from an individual’s anticipatory utility as much as it added in terms of expected health benefits.

However, it may be the case that the cost an agent incurs at $t = 2$ is not subtracted from a global budget. For example, in the case of practicing safe sex, the main cost

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11 In this formulation of anxiety, it is assumed that the cost of the health care investment $c$, or the expected consumption loss it entails, also causes anxiety. Proposition 4 goes through for a notion of anxiety that does not account for the investment cost in this way.
of investing in prevention may stem from exerting willpower at $t = 2$. But although resisting temptation at $t = 2$ comes at a real cost, it may not make the agent feel any worse at $t = 3$. If this is the case, someone with a higher propensity to feel anxious, i.e. an individual with a higher $s$, may invest more because she places a higher value on $t = 3$ payoffs and $c$ is not subtracted from these payoffs.

Anxiety-driven investments in prevention are likely to be more prevalent where the investment cost mostly consists of effort, as in the case of abstaining from risky sex, exercising more, or obtaining HIV mother to child transmission prevention from a far away clinic. The case of the baseline model is probably more pertinent to financially expensive preventative or diagnostic measures. Of course, relative to low incomes in developing countries many prevention technologies are expensive. In the developed world, CAT scans serve as an example of the baseline model’s assumption. Also captured by the baseline model are preventative technologies that exacerbate the adverse consequences of being infected even though they lower the probability of infection, e.g. malaria prophylaxis.

Anxiety-driven health investments occur when the agent’s $t = 2$ expected utility can be written as

$$
E_1 \left[ U(\hat{\theta}, x, c) \right] + sE_1 \left[ U(\hat{\theta}, x) \right] = x \left( \alpha V + (1 - \alpha)[(1 - \bar{\theta})V + \bar{\theta}(V - L)] - c \right) + xs \left( \alpha V + (1 - \alpha)[(1 - \bar{\theta})V + \bar{\theta}(V - L)] \right) + (1 - x)(1 + s) \left( (1 - \bar{\theta})V + \bar{\theta}(V - L) \right)
$$

with the difference to the baseline case being that the $xs$ term now no longer features a $c$. The agent will therefore invest if $(1 + s)\alpha\bar{\theta}L > c$. Holding $\bar{\theta}$ constant, anxiety now increases an individual’s propensity to invest in prevention at $t = 2$. However, since $\bar{\theta}$ is still decreasing in $s$ (though less steeply), the effect of an increase in $s$ on the demand for health insurance is ambiguous.

**Proposition 5.** Suppose $t = 2$ utility is given by (8). Then the demand for prevention $D^d_s$ is

- weakly increasing in $s$ if $2\alpha\theta L > \bar{c}$,
- and weakly decreasing in $s$ if $2\alpha\theta L < \bar{c}$.

In affluent settings with a well functioning health sector or for conditions for which there exists a sufficiently effective and cheap prevention technology, higher innate anxiety or salience of future outcomes may thus lead to more prevention. As will be discussed in more detail in section 4, the likelihood of success of a campaign to raise $s$, for example, by increasing the salience of adverse outcomes, thus crucial depends on the environment in which it is set. The other main predictions of the model are unperturbed by allowing
anxiety to drive health investments.

3 The market for prevention technologies

I now turn to analyzing the incentives faced by a firm that sells prevention technologies to denialists. Suppose an individual still faces a stochastic investment cost \( c \) that is uniformly distributed on the support \([0, \bar{c}]\) and captures the willpower required for adherence or the difficulty of reaching a health care facility. However, investing in prevention now also entails paying a deterministic price \( p \) to the firm selling the technology at \( t = 2 \).

The timing in Figure 1 is modified by adding a stage at \( t = 0 \) in which the monopolist posts a price \( p \) or in the case of competition, several firms simultaneously post prices. I assume that firms commit to the prices they post, so that at \( t = 2 \), after an agent has chosen her beliefs, but before she makes her purchasing or investment decision, prices cannot be changed anymore.

The agent’s \( t = 2 \) expected utility is now given by

\[
\mathbb{E}_2 \left[ U (\tilde{\theta}, x) \right] = x (1 + s) \left( \alpha V + (1 - \alpha) [(1 - \tilde{\theta}) V + \tilde{\theta} (V - L)] - c - p \right) \\
+ (1 - x) (1 + s) \left( (1 - \tilde{\theta}) V + \tilde{\theta} (V - L) \right)
\]

where \( x \in \{0, 1\} \) takes a value of 1 if the individual decides to invest. Investment thus occurs when \( \alpha \tilde{\theta} L > c + p \) and the agent’s \( t = 1 \) utility is given by

\[
\mathbb{E}_1 \left[ U (\theta, \tilde{\theta}) \right] + s \mathbb{E}_1 \left[ U (\tilde{\theta}, \tilde{\theta}) \right] = \\
\int_{\alpha \tilde{\theta} L - p}^{\alpha \tilde{\theta} L - \bar{c}} \alpha V + (1 - \alpha) [(1 - \theta) V + \theta (V - L)] - c - p \ dF(c) \\
+ \int_{\alpha \tilde{\theta} L - p}^{\bar{c}} (1 - \theta) V + \theta (V - L) \ dF(c) \\
+ s \int_{\alpha \tilde{\theta} L - p}^{\alpha \tilde{\theta} L - p} \alpha V + (1 - \alpha) [(1 - \tilde{\theta}) V + \tilde{\theta} (V - L)] - c - p \ dF(c) \\
+ s \int_{\alpha \tilde{\theta} L - p}^{\bar{c}} (1 - \tilde{\theta}) V + \tilde{\theta} (V - L) \ dF(c)
\]

The agent chooses the belief that maximizes her expected utility at \( t = 1 \), which yields the following optimal belief

\[
\tilde{\theta}^*(p) = \max \left[ \frac{\theta}{1 - s} - \frac{s (\bar{c} + \alpha p)}{(1 - s) \alpha^2 L}, 0 \right]
\]
and induces the following demand conditional on price

\[ D^d(p) = \begin{cases} \frac{\alpha \theta L - p}{(1-s)c} - \frac{s}{(1-s)\alpha}, & \text{if } \alpha^2\theta L > s(c + \alpha p) \\ 0, & \text{otherwise} \end{cases} \tag{9} \]

At \( t = 0 \) a firm anticipates the effect of its price on beliefs and demand and chooses its price so as to maximize profits

\[ \pi = p D^d(p). \tag{10} \]

Implicit in (10) is the assumption that the prevention technology’s marginal production cost is zero. This assumption is not crucial, but has the benefit of allowing us to interpret the results of previous sections as the competitive market outcome. Letting the subscript \( m \) denote monopoly outcomes, the following proposition characterizes the market equilibrium in the case of a single firm.

**Proposition 6.** If \( \alpha^2\theta L < s\bar{c} \), there is zero demand for the prevention technology at any price. If \( \alpha^2\theta L > s\bar{c} \), a monopoly firm charges price

\[ p^*_m = \frac{1}{2} \alpha \theta L - \frac{s}{\alpha} \bar{c} \]

and thereby induces belief

\[ \tilde{\theta}^*_m = \frac{(1 - 2s)\theta}{2 - 2s} - \frac{s(2 - s)\bar{c}}{2(1 - s)\alpha^2 L} \]

and demand

\[ D^d_m = \frac{1}{2} \left( \frac{\alpha \theta L}{(1-s)c} - \frac{s}{(1-s)\alpha} \right). \]

The monopolist responds to the agent’s behavioral bias by lowering prices, and the equilibrium price is therefore lower for a higher \( s \). In a sense, the agent has a psychological substitute good at her disposal, which involves not purchasing the prevention technology and dreaming of a healthy future. To keep the agent from biasing her beliefs too far, the monopolist thus needs to give up a material rent in the form of a lower price.

When firms compete, I assume that, in the case of two or more firms posting the lowest price, they have an equal probability of selling to the agent. The following proposition then characterizes the equilibrium when there is more than one firm posting prices at \( t = 0 \) and firms’ prevention technologies are perfect substitutes.

**Proposition 7.** If \( \alpha^2\theta L < s\bar{c} \), there is zero demand for the prevention technology at any
price. If $\alpha^2 \theta L > s \bar{c}$, competitive firms charge price $p_c^* = 0$ and thereby induce belief

$$\tilde{\theta}_c = \frac{\theta}{1 - s} - \frac{s \bar{c}}{(1 - s) \alpha^2 L},$$

and demand

$$D_c^d = \frac{\alpha \theta L}{(1 - s) \bar{c}} - \frac{s}{(1 - s) \alpha}.$$

There is nothing in our consumer’s psychology that implies that firms would not compete in prices. By a typical Bertrand logic, competition thus leads to marginal cost pricing. Propositions 6 and 7 tell us that we expect more consumer optimism in monopolistic settings. As lack of competition gives rise to higher prices, consumers of the prevention technology find it more and more worthwhile to switch to their psychological substitute good, i.e. denial.

By comparing $D_c^d$ and $D_m^d$, we can study the effect of competition, and thus competition policy, on the demand for prevention. Since we know from previous sections that an increase in the exogenous expected investment cost has a disproportionately large impact on the demand of denialists compared to realists, we may expect motivated denial to provide a strong case for competition policy as a tool for increasing demand. The following proposition shows that, because the monopolist prices strategically, this intuition is wrong and that the opposite is true.

**Corollary 3.** An increase in competition brings about a smaller increase in demand when the agent is a denialist ($s > 0$) than when she is a realist ($s = 0$), i.e.

$$D_c^d(s = 0) - D_m^d(s = 0) > D_c^d(s > 0) - D_m^d(s > 0)$$

The underlying reason for this result is that the monopolist compensates for the demand-reducing effect of denial by charging lower prices in the case of $s > 0$. Since $p_m^*(s = 0) > p_m^*(s > 0)$ and $p_c^*(s = 0) = p_c^*(s > 0) = 0$, corollary 3 also implies that the decrease in material welfare a consumer experiences as the market for prevention becomes more monopolistic is smaller if she is a denialist ($s > 0$) rather than a realist ($s = 0$).

Since both the price a monopolist can charge and the demand she faces are decreasing in $s$, her profits also decrease with $s$. A monopolist would thus have an incentive to deploy any marketing tool that limits $s$ and, therefore, the agent’s incentive to engage in denial. If she can, the monopolist will also try to hamper the agent’s denial technology, i.e. decrease her ability to engage in denial. This may be done, for example, by using advertisements and informercials to frequently remind consumers of the risks they face.

The monopolist in my model cannot benefit from the behavioral aspects of the consumer’s personality because she is selling a product that becomes more desirable the
more at risk an agent feels and she therefore cannot exploit consumer optimism. The monopolist would want to offer bets whose payoffs are contingent on the realization of the consumer’s health. Such bets could discipline the consumer's beliefs or, where this is more profitable, exploit them. However, the technical and legal difficulties involved in first verifying that someone is sick ex post and then making them pay for it can probably account for the absence of such instruments in the market place for prevention. Of course, in other markets instruments like this exist. For example, Bridet and Schwardmann (2014) show that in lending markets, collateral may be used to make a denialist pay for her optimism.

4 Policy implications

The motivated denial or optimal expectations framework highlights an important question regarding the social welfare function a policy maker should seek to maximize: Should a social planner, like the agent at stage \( t = 1 \), take into account a weighted sum of physical and psychological utility, or should she be focussing on physical and health outcomes only?

It may be argued that it is health outcomes that exert externalities and should therefore be the primary focus of government intervention. Most of the statistics that are used to guide and appraise policy interventions are indeed concerned with physical outcomes. For the sake of the discussion that follows, I will therefore take the view that a social planner seeks to maximize material payoffs. Then her task is one of discouraging denial, because denial may lead to bad decisions while never adding to social welfare. Furthermore, denial may be undesirable independent of its effect on an individual’s protective efforts when information spreads through networks and individuals do not fully account for the negative externality that their uninformedness has on others, such as dependents who seek to learn from them.

Nevertheless, an individual’s psychological wellbeing also matters. Many therapists would argue that a person who is anxious and lacks hope (i.e. whose psychological payoff is low) can exert significant negative externalities on those around her. In this view, denial can serve a useful purpose.

4.1 Governments should favor improving the effectiveness of the prevention technology over subsidizing prevention.

In the presence of denialists, improvements in \( \alpha \) can pay large dividends. To see this, recall that a technology with low \( \alpha \) incentivizes denial in two ways. First, if \( \alpha \) is low, it is unlikely that biased beliefs are costly in material terms, because there are fewer cost realizations for which an individual would actually invest. Second, even in states of the world in which an individual invests, there remains a large chance that the
prevention technology fails and there thus remains a lot to worry about, which implies large psychological payoffs from denial. Reducing the expected cost of prevention $\bar{c}$, on the other hand, only affects denial in that it makes it more likely that the agent finds herself in the state of the world in which denial causes her to pass on a very profitable health investment.

As a result, a social planner who wants to increase the demand for prevention by allocating a limited health budget to either subsidies or improvements to $\alpha$, i.e. the effectiveness of the prevention technology, should spend relatively more on R&D for improving $\alpha$ when she is facing denialists rather than realists. Put differently, a social planner who uses a model based on realistic agents to come up with her policy option may overinvest in subsidies compared to R&D.

To make this argument more precise consider the denialist’s demand in (9) when she faces a monopolist and define the realist’s demand as $D_r \equiv D_d(s = 0)$. The government seeks to maximize $D(p - \gamma_p, \alpha + \gamma_\alpha)$ subject to a limited health budget $B$. $\gamma_p$ is the price subsidy and $\gamma_\alpha$ the improvement in the technology that is based on government R&D. I assume that the government’s cost function is given by $F(\gamma_p, \gamma_\alpha) = \gamma_p + C(\gamma_\alpha)$, where $C'(\gamma_\alpha) > 0$ and $C''(\gamma_\alpha) > 0$. So the government can costlessly raise money and subsidize consumption (up to a constraint $B$), but R&D yields diminishing returns.

Let $\gamma_p^d$ and $\gamma_\alpha^d$ denote the solution to the social planner’s program when she faces denialists and let superscript $r$ stand for realists.

**Proposition 8.** A social planner that faces denialists and seeks to maximize $D_d(p - \gamma_p, \alpha + \gamma_\alpha)$ will invest relatively more in improvements in $\alpha$ than a social planner that faces realists and seeks to maximize $D_r(p - \gamma_p, \alpha + \gamma_\alpha)$, i.e. $\frac{\gamma_\alpha^d}{\gamma_\alpha^r} < \frac{\gamma_p^d}{\gamma_p^r}$.

### 4.2 Information campaigns have variable success.

Dupas (2011) cites several examples of both successful and unsuccessful information campaigns in terms of their effect on health behavior. In settings in which the returns to preventative health care investments are large and misinformation prevalent, it is perhaps the unsuccessful information campaigns that are surprising. My model predicts that even in cases of rampant ex ante optimism, a signal sent by a policy maker about the true risk of infection $\theta$ may have little effect on ex post beliefs and actions if the incentives to engage in denial are not removed. In this context, information campaigns are less likely to have an effect by themselves and need to be accompanied by more comprehensive interventions.

Nonetheless, as Oster et al. (2013a) show, being confronted with irrefutable hard evidence (e.g. in the form of a genetic test) may seriously hamper an educated individual’s ability to engage in denial. This highlights the importance of gaining a better understanding of how interventions can hope to constrain individual’s tendency to self-deceive. In any case, if motivated denial is the cause of misinformation, the policy makers task
is not so much to inform the public, as it is to persuade it. How best to persuade a denialist is an important question for future research.

4.3 Scaring people may not increase preventative efforts.

Suppose that a policy maker has some control over the salience of future payoffs $s$ or that she is in some way able to increase agents’ propensity to feel anxious. For example, screening infomercials or putting warning labels that highlight the adverse consequences of a health condition on harmful products may be policy measures that can hope to bring about an increase in $s$.

Whether such policy measures succeed in increasing prevention then crucially depends on whether anxiety drives health investments. In the baseline model, in which the investment cost is subtracted from a global budget, increasing $s$ is counterproductive in that it leads to more denial and less demand for prevention. However, as we saw in section 2.5, this need not be the case when the investment is made up of costs that are less transferable across time, for example, when it involves exerting effort rather than incurring a monetary cost.

Even when increasing $s$ may increase prevention, according to proposition 5, scare tactics are more likely to work in rich country settings, where individuals are truly empowered to take action. Similarly, warning labels on alcohol and cigarettes may decrease consumption and increase cessation for moderate smokers and drinkers, but lead to an increase of denial and consumption for addicts and heavy users for whom the costs of cessation are very high. My model may thus help understand where and why there are boomerang effects to warning labels on harmful products (see Robinson and Killen, 1997 and Ringold, 2002).

Furthermore, even if anxiety has a direct effect on preventative effort, as in section 2.5, proposition 5 implies that development agencies should be careful in exporting successful scare tactics from developed- to developing-country contexts, where they might backfire.

4.4 It may pay to overstate the risks and costs associated with a disease and the ease of avoiding it.

Policy makers and health practitioners that are able to influence individuals’ perception of key variables and that are interested in maximizing physical payoffs, will downplay the cost of prevention and exaggerate its effectiveness as well as the individual’s true risk of infection and cost of being infected. Exaggeration can hope to restore decisions at $t = 2$ that are physically optimal. Exaggeration that maximizes material payoffs would be more severe for smaller risks, larger losses and a less effective prevention technology. Exaggeration, however, relies on some naïveté on behalf of agents, since perfect knowledge of a policy maker’s objective and a Bayesian interpretation of the signals she sends would thwart any efforts to exert real influence over an agent’s perception. Furthermore,
a warning about the size of the loss $L$ may also increase $s$ and thus, as discussed in the previous section, run the risk of increasing, instead of decreasing, denial.

5 Conclusion

This paper focusses on why an individual may have an incentive to engage in self-deception and how this incentive varies with the environment. I make a simplistic assumption about the supply side of self-deception or, put differently, how an individual biases her beliefs: in my model, beliefs are simply chosen by the agent. The conclusions I reach making this assumption would go through if we assumed an exogenous cognitive cost of self-deception, regardless of whether this cost was fixed or increasing with the distance between $\tilde{\theta}$ and $\theta$.

In reality, an individual’s ability to self-deceive may be impacted upon by a myriad of factors. Because economists and psychologists still know very little about these factors, freely chosen beliefs may constitute the best assumption at this point. But insights into the supply side of self-deception are starting to accrue. For example, self-deception seems to require vagueness (Sloman et al., 2010). Furthermore, the placebo effect and the prevalence of quacks, homoeopathy and ineffective, but expensive, nutritional supplements suggest that people often rely on tools or outside help to better achieve self-deception. A better understanding of how the ability to self-deceive interacts with factors in the environment is likely to greatly improve our understanding of the distribution of optimistic beliefs across different settings and individuals. It would also provide insights into multi-billion dollar industries around products like nutritional supplements.

The motivated denial of health risks is likely to play an important role in insurance markets. By setting contractual terms, insurance providers are likely to exert some influence over insurees’ incentives to engage in denial. Sandroni and Squintani (2007) study the case of exogenously optimistic agents in a Rothschild and Stiglitz (1976) model, while Bridet and Schwardmann (2014) show that the presence of denialists interacts with information asymmetries in lending markets in an interesting way. Explicitly accounting for motivated beliefs in insurance markets with informational asymmetries could shed new light on where to expect insurance rejections and where to expect adverse as opposed to advantageous selection.

References


A Proofs

A.1 Proposition 1

Unconstrained maximization of (3) with respect to \( \tilde{\theta} \) yields the following first order condition

\[
\frac{L(\alpha^2 \theta L - (1 - s)\alpha^2 \tilde{\theta} L - s \bar{c})}{\bar{c}} = 0
\]  

(11)

Let \( \tilde{\theta}_{sol} \) denote the \( \tilde{\theta} \) that solves (11). The second derivative of (3) with respect to \( \tilde{\theta} \), i.e. 

\[
-\frac{(1-s)\alpha^2 L^2}{\bar{c}}
\]

is negative everywhere provided that the assumption that \( s < 1 \) holds. So (11) characterizes a global maximum. Furthermore, if \( \tilde{\theta}_{sol} \leq 0 \) then any \( \tilde{\theta}' > 0 \) yields less expected utility than \( \tilde{\theta}'' = 0 \). Since the agent cannot believe in negative probabilities, \( \tilde{\theta}_{sol} \leq 0 \) then implies that the optimal belief is \( \tilde{\theta}^* = 0 \). When \( \tilde{\theta}_{sol} > 0 \), then \( \tilde{\theta}^* = \tilde{\theta}_{sol} \).
A.2 Corollary 1

When $\tilde{\theta}^* = 0$, $\frac{\partial \Delta}{\partial z} = 0$ for $z \in \{c, \alpha, L, s\}$, when $\tilde{\theta}^* > 0$, i) $\frac{\partial \Delta}{\partial c} = \frac{s}{(1-s)\alpha^2L}$ is positive; ii) $\frac{\partial \Delta}{\partial \alpha} = -\frac{2sc}{(1-s)\alpha^2L}$ is negative; ii) $\frac{\partial \Delta}{\partial L} = -\frac{sc}{(1-s)\alpha^2L}$ is negative; iv) $\frac{\partial \Delta}{\partial \theta} = -\frac{s}{(1-s)\alpha^2L}$ is negative; and v) $\frac{\partial \Delta}{\partial s} = \frac{\tilde{c} - \theta \alpha^2L}{(1-s)\alpha^2L}$ is positive because $\tilde{c} > \theta \alpha^2L$ by assumption 1.

A.3 Proposition 2

When $D^d > 0$ then $D^r - D^d = \frac{s(\tilde{c} - \theta \alpha^2L)}{(1-s)\alpha^2}$ is positive because $\tilde{c} > \theta \alpha^2L$ by assumption 1. When $D^d = 0$, then $D^r - D^d = D^r > 0$. Furthermore, i) $\frac{\partial(D^r - D^d)}{\partial c} = \frac{s\theta \alpha L}{(1-s)\tilde{c}^2} > 0$, ii) $\frac{\partial(D^r - D^d)}{\partial \alpha} = -\frac{s\theta L}{(1-s)\tilde{c}^2} < 0$ and iii) $\frac{\partial(D^r - D^d)}{\partial L} = -\frac{s\theta \alpha}{(1-s)\tilde{c}^2} < 0$.

A.4 Proposition 3

First note that the realist’s demand elasticities take the following simple form: $\eta^r_\alpha = 1$, $\eta^r_L = 1$, $\eta^r_\theta = 1$ and $\eta^r_s = -1$. The denialist’s elasticities of demand on the other hand are given by

$$\eta^d_\alpha = \frac{\alpha^2 \theta L + \tilde{c}}{\alpha^2 \theta L - \tilde{c}} > 1,$$

$$\eta^d_L = \eta^d_\theta = \frac{\alpha^2 \theta L + \tilde{c}}{\alpha^2 \theta L - \tilde{c}} > 1,$$

and $\eta^d_s = \eta^d_\theta = -\frac{\alpha^2 \theta L}{\alpha^2 \theta L - \tilde{c}} < -1$.

This establishes the first column of inequalities in the proposition.

The exogenous optimist’s elasticities are given by $\eta^o_\alpha = \eta^o_L = 1$, $\eta^o_\theta = -1$ and $\eta^o_s = 0$ if she remains optimistic about the risk of infection.\(^{12}\)

A steep discounter’s elasticities are given by $\eta^m_\alpha = 1$, $\eta^m_L = 1$, $\eta^m_\theta = 1$ and $\eta^m_s = -1$ and are thus identical to the realist’s.

The liquidity constrained agent has demand that is completely unresponsive to small changes in $\alpha$, $L$ and $\theta$, i.e. $\eta^m_\alpha = 0$, $\eta^m_L = 0$, $\eta^m_\theta = 0$. We do, however, have that $\eta^m_s = -1$.\(^{13}\)

A.5 Corollary 2

We arrive at this result by taking the first derivative of the difference between the two elasticities in questions, i.e. $\frac{\partial(\eta^s_\theta - \eta^s_\theta)}{\partial \tilde{c}} = -\frac{s\alpha^2 \theta L}{(\alpha^2 \theta L - \tilde{c})^2} < 0$.

\(^{12}\)Of course, simply informing an exogenous optimist of her mistaken beliefs may lead to a large increase in demand, even if $\theta$ does not change.

\(^{13}\)The result that the price elasticities are the same for a liquidity constrained agent as they are for a realist derives from the fact that I assume a uniform cost distribution.
A.6 Proposition 4

When \( \alpha^2\theta L < s\bar{c} \), then \( \tilde{\theta}^* = 0 \), \( A = 0 \) and \( \frac{\partial A}{\partial \bar{c}} = 0 \). When \( \alpha^2\theta L > s\bar{c} \) then

\[
\frac{\partial A}{\partial \bar{c}} = \frac{s(\alpha^2\theta L - (2s - s^2)\bar{c})}{(1 - s^2)\alpha^2}
\]

By assumption 1, the smallest possible level of \( \bar{c} \) is \( \bar{c}_s = \alpha\theta L \). Note that \( \frac{\partial A}{\partial \bar{c}} \) is negative at \( \bar{c}_s \) because \( \alpha < (2s - s^2) \). Since \( \frac{\partial A}{\partial \bar{c}} \) is decreasing in \( \bar{c} \), it is then negative everywhere.

A.7 Proposition 5

We can rewrite (3) to account for the facts that \( c \) is not subtracted from an individual's anticipatory utility and that the investment decision is governed by (8)

\[
\mathbb{E}_1\left[U(\theta, \tilde{\theta})\right] + s\mathbb{E}_1\left[U(\tilde{\theta}, \tilde{\theta})\right] = \\
\int_0^{(1+s)\alpha\theta L} \alpha V + (1 - \alpha)[(1 - \theta)V + \theta(V - L)] - c \ dF(c) \\
+ \int_{(1+s)\alpha\theta L}^{\bar{c}} (1 - \theta)V + \theta(V - L) \ dF(c) \\
+ s\int_0^{(1+s)\alpha\theta L} \alpha V + (1 - \alpha)[(1 - \tilde{\theta})V + \tilde{\theta}(V - L)] \ dF(c) \\
+ s\int_{(1+s)\alpha\theta L}^{\bar{c}} (1 - \tilde{\theta})V + \tilde{\theta}(V - L) \ dF(c)
\]

Solving as we solved the baseline model, optimal beliefs and demand are then given by

\( \tilde{\theta}_s = \max \left[ \frac{\theta}{1-s} - \frac{s\bar{c}}{(1-s^2)\alpha\theta L}, 0 \right] \) and

\[
D^d_s = z \int_0^{(1+s)\alpha\tilde{\theta} L} f(c) \ dc \\
= \begin{cases}
\frac{(1+s)\alpha\theta L}{(1-s)\bar{c}} - \frac{s}{(1-s)\alpha} & \text{if } (1 + s)\alpha^2\theta L > s\bar{c} \\
0 & \text{otherwise}
\end{cases}
\]

respectively. In accordance with intuition, anxiety-driven demand is therefore higher than demand in the baseline model. When \( D^d_s = 0 \) then \( \frac{\partial D^d_s}{\partial s} = 0 \). When \( D^d_s > 0 \) taking the first derivative of \( D^d_s \) w.r.t. \( s \) yields

\[
\frac{\partial D^d_s}{\partial s} = \frac{2\alpha^2\theta L - \bar{c}}{(1-s)^2\alpha\bar{c}}
\]

The sign of the first derivative is therefore the same as the sign of the expression \( 2\alpha^2\theta L - \bar{c} \).
A.8 Proposition 6

When $\alpha^2 \theta L > s \bar{c}$, profit is given by

$$\pi = p D_d(p) = p \left( \frac{\alpha \theta L - p}{(1-s)\bar{c}} - \frac{s}{(1-s)\alpha} \right).$$

(12)

as long as $p$ is small enough, i.e. as long as $p$ satisfies $\alpha^2 \theta L - s \bar{c} > p$. Since (13) is strictly concave in price, the monopoly obtains its optimal price by setting the first derivative of $\pi$ w.r.t. $p$ equal to zero. We thus obtain

$$p^*_m = \frac{1}{2} \alpha \theta L - \frac{s}{\alpha} \bar{c}$$

which satisfies $\alpha^2 \theta L - s \bar{c} > p$ because

$$\alpha^2 \theta L - s \bar{c} > \frac{1}{2} \alpha \theta L - \frac{s}{\alpha} \bar{c}$$

$$\left( \frac{2\alpha - 1}{2\alpha - 2} \right) \alpha^2 \theta L > s \bar{c}$$

and $\frac{2\alpha - 1}{2\alpha - 2} > 1$ for all $\alpha$. $\tilde{\theta}_m^*$ and $D_m^d$ are obtained by substituting $p_m^*$ into $\tilde{\theta}^*(p)$ and $D^d(p)$ respectively.

A.9 Proposition 7

It needs to be proved that the competitive equilibrium gives rise to firms charging $p = 0$. Beliefs and allocations then follow from the baseline model. Without loss of generality suppose there are only two firms in the market, firm A and firm B. Suppose that firm A charges $p_A = 0$ and firm B charges $p_B = 0$. Then both firms make zero profits. There exists not profitable deviation for firm B, since charging $p_B > 0$ results in no demand for its product, and, hence, zero profits, and charging $p_B < 0$ yields $\pi_B < 0$ because demand will be positive, but sales are associated with a loss. $p_A = p_B = 0$ is thus a Nash equilibrium.

Suppose now that $p_A > 0$. Then firm B can charge $p_B = p_A - \epsilon$ and earn

$$\pi_B = (p_A - \epsilon) \left( \frac{\alpha \theta L - p - \epsilon}{(1-s)\bar{c}} - \frac{s}{(1-s)\alpha} \right)$$

(13)

which, for $\epsilon$ sufficiently small, is larger than the $\pi_B = \frac{p_B}{2} \left( \frac{\alpha \theta L - p}{(1-s)\bar{c}} - \frac{s}{(1-s)\alpha} \right)$ that firm B obtains by charging $p_B = p_A$. If either firm charges a negative price and draws any demand, it can do better by raising its price. $p_A = p_B = 0$ is therefore the unique competitive equilibrium.
A.10  Corollary 3

It can be shown that $D^d_c(s = 0) - D^d_m(s = 0) > D^d_c(s > 0) - D^d_m(s > 0)$ by simply populating the expressions on both sides with the demands derived in propositions 6 and 7.

A.11  Proposition 8

The government solves the following program

$$\max_{\gamma_p, \gamma_\alpha} D(p - \gamma_p, \alpha + \gamma_\alpha) - F(\gamma_p, \gamma_\alpha)$$

s.t. $F(\gamma_p, \gamma_\alpha) = B$

The first order conditions for the case of $s = 0$ yield the expression

$$\theta_L = C'(\gamma^r_\alpha).$$

When $s > 0$ we have that

$$\theta_L + \frac{s\hat{c}}{\alpha + \gamma^d_\alpha} = C'(\gamma^d_\alpha)$$

Because $\gamma^d_\alpha \geq 0$ we have that $C'(\gamma^d_\alpha) > C'(\gamma^r_\alpha)$ and by convexity of $C(\gamma_\alpha)$ that $\gamma^d_\alpha > \gamma^r_\alpha$. The fixed budget then implies that $\gamma^d_p < \gamma^r_p$. 
