MIXED PUBLIC / PRIVATE HEALTH INSURANCE AS AN EVOLUTIONARY GAME

by

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Mixed public/private health insurance as an evolutionary game[†]

by

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Abstract

Most of the theoretical literature on private health insurance given a universal public alternative is partial equilibrium and static in nature. However, empirically, equilibria in these markets can take time to emerge and depend on other markets. This paper develops a dynamic game that describes the co-evolution of the public/private insurance *and* the public/private hospital markets. With a modest set of differential equations, a pattern of growth emerges which is distinctly non-linear.

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1 Introduction

In many health care systems, private insurance exists despite the availability of free public health insurance. An example is the British health care system, where private insurance allows one to bypass the public system's long queues as well as it's perceived low quality. The literature on public/private health insurance continues to grow (see Blomqvist and Johansson (1997) for a recent article on supplementary private insurance). However, while static partial equilibrium models dominate the theoretical literature, equilibria in practice emerge slowly and non-linearly. For an example of slowly-emerging equilibria, consider Australia's public insurance program "Medicare" (see Figure 1). In Britain, private insurance varied by over 50% from 1984 to 1990 (Besley 1999).

One reason for the slow emergence of equilibria is that, in many cases, private insurance contracts cover a fixed period, so private insurance is not instantly purchased or dropped. If people do not instantaneously purchase/drop private insurance, adverse selection, where bad risks drive up costs by selecting "good" insurance (meaning generous coverage), will take time to "play out." This means the *benefits of* purchasing private health insurance change over time.

A perhaps more important, but less understood, reason why the relative benefits of private insurance change over time is the complementarity of private care (hospital or other services) and private insurance. Public insurance in most countries cannot be used to pay for private care. Therefore, purchasers of private insurance often prefer private health care in the event of illness. This means that changes in the public sector's conges-

tion level and/or quality relative to private care will change the payoffs for purchasing private insurance. Besley, Hall, and Preston show that private insurance purchase in Britain is positively related to the length of the long term queue in the British health system (1999).[1] They also show that long-term waiting lists in Britain are positively related to the aggregate purchases of private insurance (1998). This suggests that a general equilibrium approach, where at least the insurance and providers markets are considered, is needed.

This short paper models a mixed public/private health insurance system using a multi-population replicator dynamics model with endogenous payoffs (see Beard and McDonald 1999). There are two inter-twined markets: health care providers (or hospitals, henceforth) and insurance. Both markets have public and private sectors. There is adverse selection in the insurance market and congestion in the provider market.

In replicator dynamics models, consumers do not instantly switch to the type of insurance with the highest "payoff". Rather, there is movement towards the type of insurance offering the highest payoff over time, with no guarantee of an efficient outcome. Likewise, movement towards the type of health care provider which offers the highest payoff is not instantaneous. The usual explanation is bounded rationality (Weibull 1995). However, with the issues mentioned in the previous paragraphs (long-term contracts, adverse selection, etc.), bounded rationality may not be needed as an explanation in the insurance market. Informational problems in the market for health care are thought to be widespread (Satterthwaite 1979), so bounded rationality may not be needed in that market either. In both markets, uncertainty surrounds government policy pertaining to

[1]There are numerous public choice issues in deciding the level of public provision.

public providers and/or public insurance, which means that peoples' expectations of their need for private insurance will vary over time.

Much of the existing literature is concerned with the optimality of private or private insurance when free public insurance is available. The debate mostly centers around the avoidance of moral hazard. Besley's analysis shows that moral hazard is lower when public insurance is offered because consumers may use private insurance, with its co-payments and deductibles, to cover non-catastrophic care; public insurance would be used for more serious illnesses (1989). Selden argues that there are no such welfare gains (1993). Finally, Blomqvist argues that a mixed system avoids *less* moral hazard than a purely private system (1997). Patretto considers the optimal public insurance expenditure as well as the optimal private co-insurance rate (1999). Finally, there is some relevant work on this issue outside of the health economics literature. Epple and Romano show that government provision of private goods can be majority preferred (1996). This result has implications for health insurance markets where public and private firms exist. In terms of congestion, Iverson shows that in many cases, the existence of a private sector increases public sector waiting times for providers (1997).

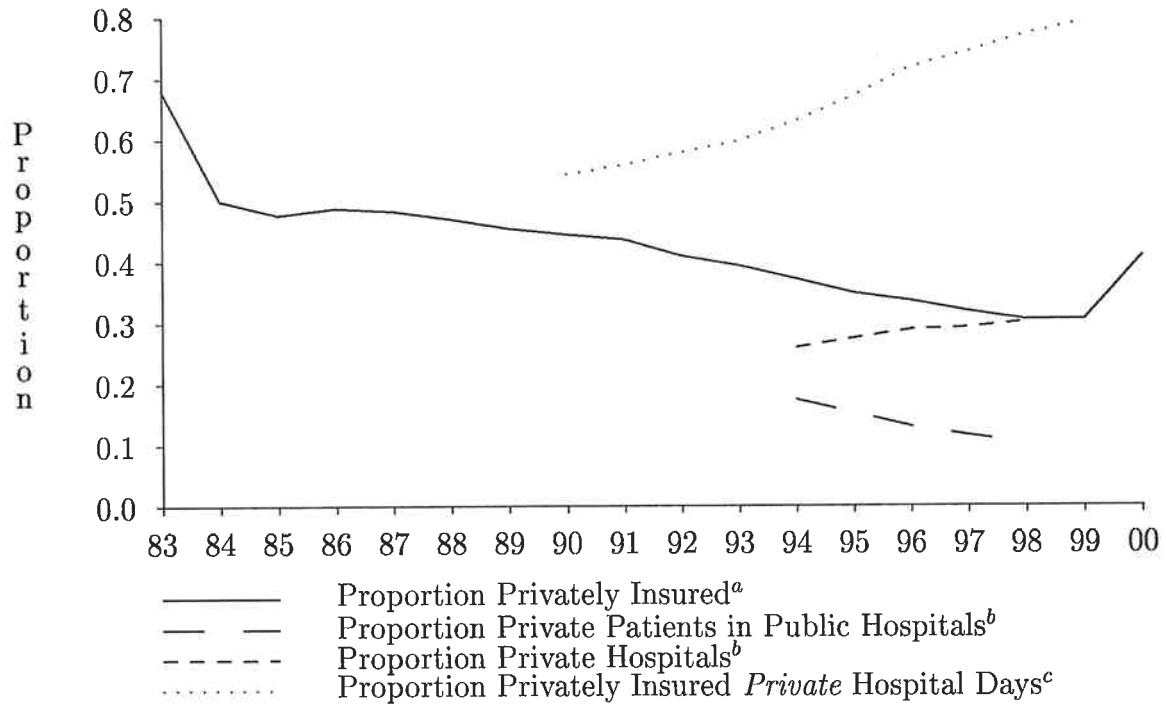
This paper abstracts from traditional welfare issues such as moral hazard which are more easily analyzed in static models. However, this paper is the first the author knows of that models health insurance as an evolutionary game.

The model has implications for policies such as tax credits for purchasing private insurance. Additionally, the model has implications for the large-scale introduction of public insurance, where private insurance dominates (such as in Australia in 1984); or, for the introduction of public insurance for a segment of the population, such as the Health

Care Financing Administration's State Children's Health Insurance Program (SCHIP) in the U.S.. The issue of public insurance crowding out private insurance is also related to this issue. However, with the approach taken in this paper, changes in the public health care provider sector affects the purchase of private insurance.

The layout of the paper is as follows. Section 2 presents the model and explains some institutional detail of the Australian system. Section 3 presents the results while Section 4 provides discussion.

Figure 1: Public and Private Proportions in the Australian Health Care System



	Source
a	PHIAC
b	Australian Hospital Statistics 1997-98 (AIHW)
c	PHIAC The Annual Report On The Operations Of The Registered Health Benefits Organisations, Part A

2 The Model

2.1 Private supplementary insurance in Australia

As is the case in static game theory, the payoffs selected will affect the outcome of the game. As far as possible, the model presented in this paper uses Australian institutions and parameters to govern the payoffs. Australian public insurance, Medicare, is representative of systems in other countries. As in other public insurance systems, people many buy private insurance in order to use private health care in the event of illness. There are subsidies to support the purchase of private health insurance. One difference in the Australian system is that, as mentioned above, Medicare is very new at 16 years old. Further, Australia's private sector, both in terms of providers and insurance, is a little "healthier" than in other countries in that 41% bought private insurance in the year 2000 (see Figure 1). One could argue that the Australian private health is "in flux," so it is an excellent system to consider.

Free care is guaranteed at public hospitals through Medicare, even to the privately insured, whom would otherwise face fees at public hospitals. Given the free alternative, it is surprising that the decline in the private insurance is so gradual (see figure 1) and that so *many* still buy private insurance.

As shown in figure 1, the privately insured in Australia are increasingly using private hospitals while Medicare users are increasingly using public hospitals (Hall, Lourenco, and Viney 1999). Changes in private hospitals may be quite important to heavy users of health services.

2.2 The replicator dynamics model

In this section, the multi-population replicator dynamics model is presented. As mentioned earlier, the model presented here differs somewhat from traditional replicator dynamics models in that the payoffs are endogenous. In addition to other static parameters, they depend on the population proportions in the two markets. Consumers choose public or private hospitals as well as whether or not to purchase private insurance. As will become clear, demand for public or private hospitals depends on whether or not they purchased private insurance in the previous period; demand for private insurance depends on anticipated demand for private hospitals in the subsequent period.

Henceforth, even though everyone is insured publicly, privately insured patients are referred to as either "insured" or "privately insured." As mentioned earlier, the term "hospital(s)" is synonymous with "care" or "provider."

Consumer health insurance demand is modeled as populations of player strategies. Let the proportion of insured patients be given by I and the proportion of Medicare only be given by M, where $I + M = 1$. Further, let H^j_{priv} and H^j_{pub} ,$j = I$ for insured or $j = M$ for Medicare, represent the proportions of sub-populations (patients) choosing private and public hospitals out of the parent populations of those who are insured and those who are not. Note that

$$H_{pub} = H^I_{pub} \cdot I + H^M_{pub} \cdot M \tag{1}$$

and

$$H_{priv} = H^I_{priv} \cdot I + H^M_{priv} \cdot M. \tag{2}$$

Note further that $H_{pub} + H_{priv} = 1$.

Let P represent the fixed price of private hospital care, paid by private users in each period whether care is receive or not. Consumers with private insurance pay a fraction of the full price, $\beta \cdot P, \beta \in (0,1)$ for private care; those with Medicare pay P for private care. Because the insured will likely use Medicare when they use public hospitals to avoid co-payment, let us assume public hospitals have zero out-of-pocket expenses for everyone. However, let there be congestion costs of $w \cdot (H_{pub})^{\alpha}$, where w is the wage and α is the congestion factor. Note that $\alpha > 1$, congestion always increases as more people use public hospitals.

The fact that everyone can use public hospitals for free by default means that the traditional risk aversion motive for purchasing private insurance is greatly reduced because private insurance mainly covers gaps in coverage. Let us therefore ignore risk aversion as a motive for purchasing private insurance. Let us suppose that there is a proportional rebate, $R \in (0,1)$, for buying private health insurance. Let there be laws against price discrimination so that the premium is community rated. Suppose further that the insurance market is competitive. Then consumers will pay

$$\Pi = (1 - R) \cdot (1 - \beta) \cdot P \cdot H^I_{priv} \tag{3}$$

per period for health insurance. Notice that as more people who are insured buy private

health care, the premium increases.

Following Feldman-Dowd (1982, 1991), let the preference for private care relative to public care be given by the monetary index

$$\Psi = c + (\gamma(1 - H_{priv}))^a, \tag{4}$$

where $c \geq 0, a \geq 0$, and γ are parameters. Notice that the first patients using private hospitals have the strongest preference for private care. These are the heavy users of health care. On the other hand, notice that Ψ is at its minimum for the last or most healthy person using private care. Suppose that the consumer on the continuum from healthiest to sickest is indifferent between private and public hospitals, all else equal, at the proportion H^*_{priv}. Then the $1 - H^*_{priv}$ consumers who use private hospitals are heavier users on average than the indifferent consumer; the $1 - H^*_{priv}$ consumers who use public are lighter users on average than the indifferent consumer.

2.2.1 Payoffs for choosing public or private hospitals, contingent on insurance

We have four payoffs for consumers using all types of hospitals, which are *contingent* on being insured. They are

$$\delta^I_{priv} = w \cdot H^{\alpha}_{pub} - \beta \cdot P + \Psi \tag{5}$$

for the insured using private care,

$$\delta^{I}_{pub} = \beta \cdot P - w \cdot H^{\alpha}_{pub} - \Psi \tag{6}$$

for the insured using public care,

$$\delta^{M}_{priv} = w \cdot H^{\alpha}_{pub} - P + \Psi \tag{7}$$

for Medicare holders using private care, and

$$\delta^{M}_{pub} = P - w \cdot H^{\alpha}_{pub} - \Psi \tag{8}$$

for Medicare holders using public care.

Let us consider (5) as an example. The relative payoff for private hospital care, conditional on the purchase of private insurance, increases as the relative price of private hospital care falls. Further, the payoff for private hospital care increases as Ψ increases because the monetized preference for private hospital care is high. Note from (5) and (6) that $\delta^{I}_{pub} = -\delta^{I}_{priv}$; from (7) and (8) that $\delta^{M}_{pub} = -\delta^{M}_{priv}$.

2.2.2 Payoffs for insurance

Now let us consider the decision to become insured. The payoffs of purchasing private insurance depend on whether the consumer chooses public or private hospital care. Let us suppose that private hospital care is chosen. Then, from (7) and (5), the payoff for

buying insurance is

$$\Delta^I_{priv} = \delta^M_{priv} - \delta^I_{priv} - \Pi. \tag{9}$$

The payoff for buying insurance when public hospital care is chosen is symmetrically

$$\Delta^I_{pub} = \delta^M_{pub} - \delta^I_{pub} - \Pi. \tag{10}$$

The average payoff for buying private insurance is

$$\Delta^I = H^I_{priv} \cdot \Delta^I_{priv} + H^I_{pub}\Delta^I_{pub}. \tag{11}$$

Likewise, from (8) and (6), the payoff for not buying buying insurance when private hospital care is chosen is

$$\Delta^M_{priv} = \delta^I_{priv} - \delta^M_{priv} + \Pi; \tag{12}$$

and

$$\Delta^M_{pub} = \delta^I_{pub} - \delta^M_{pub} + \Pi; \tag{13}$$

when public hospital care is chosen. The average payoff for *not* buying private insurance is

$$\Delta^M = H^M_{priv} \cdot \Delta^M_{priv} + H^M_{pub}\Delta^M_{pub}. \tag{14}$$

2.3 Dynamics

The dynamics of player strategy proportions are modeled using standard multi-population replicator dynamics. The basic idea is as follows. if the average payoff for all choices exceeds the payoff for a particular choice, such as choosing a private hospital, there is movement away from that choice; if the average payoff is less than the payoff for a particular choice, there is movement toward that choice. If the average payoff equals the payoff for a particular choice, there is no movement towards or away from that choice.

2.3.1 Population movements in the hospital market, contingent on insurance

First, let us consider the sub-population of the insured. The differential equation which describes movement towards or away from private hospital care through time is given by

$$\dot{H}^I_{priv} = (\Delta^I_{priv} - \Delta^I) \cdot H^I_{priv}.$$

Note that Δ^I is the average payoff for the privately insured, given by (11). Among this sub-population, if the payoff from private hospital service is higher than the average payoff, there is movement towards using private hospitals and vice-versa. Symmetrically, the differential equation which describes movement towards or away from public hospital care through time is given by

$$\dot{H}^I_{pub} = (\Delta^I_{pub} - \Delta^I) \cdot H^I_{pub}.$$

Now let us consider the Medicare-only sub-population. The differential equation which describes movement towards or away from private hospital care through time is

given by

$$\dot{H}^M_{priv} = (\Delta^M_{priv} - \Delta^M) \cdot H^M_{priv}.$$

$$\dot{H}^M_{pub} = (\Delta^M_{pub} - \Delta^M) \cdot H^M_{pub}.$$

Note that Δ^M is the average payoff for Medicare, given by (14).

2.3.2 Population movements in the insurance market

Finally, let us consider the differential equations for buying or not buying insurance. The equation for buying insurance is

$$\dot{I} = (\Delta^I - (I \cdot \Delta^I + M \cdot \Delta^M)) \cdot I$$

where M is the proportion of the total population using Medicare. Note that $I \cdot \Delta^I + M \cdot \Delta^M$ is the average payoff for the insured and Medicare combined. Symmetrically, the equation for Medicare is

$$\dot{M} = (\Delta^M - (I \cdot \Delta^I + M \cdot \Delta^M)) \cdot M.$$

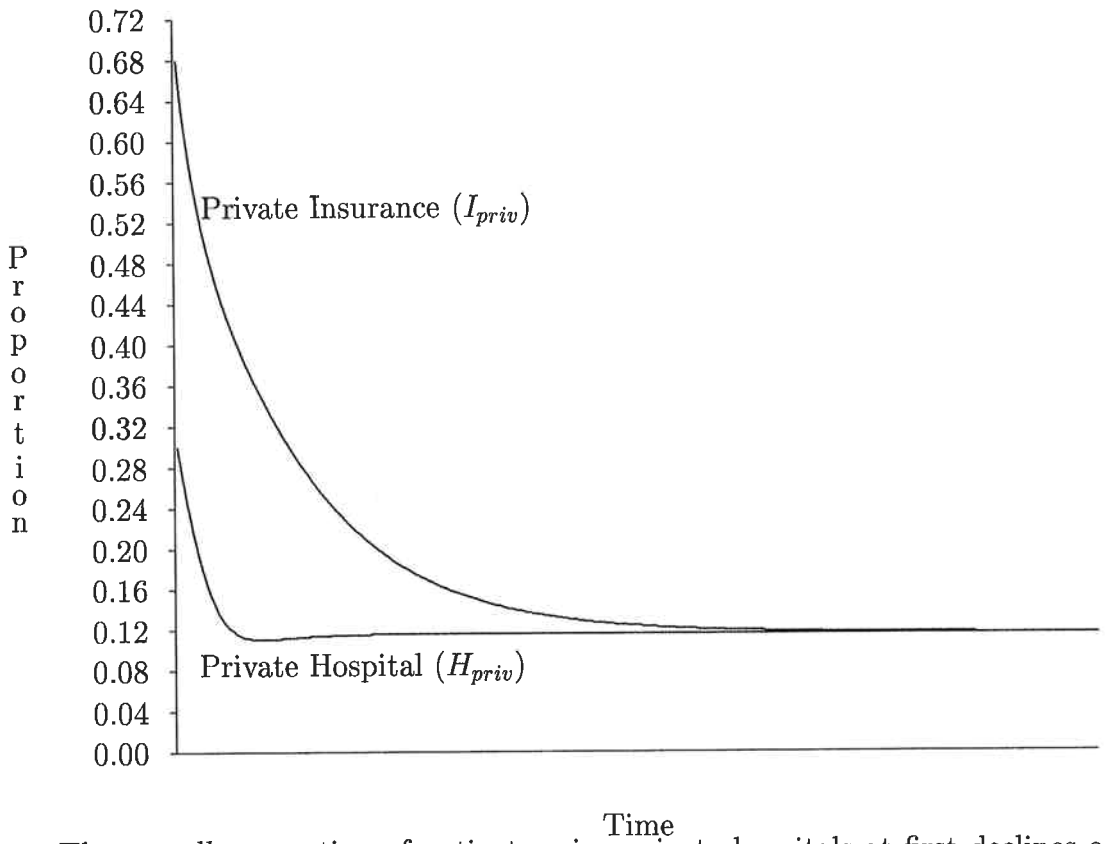
The system of six equations are solved numerically using a first-order Euler method. The starting values and parameters are given in Table 1.

3 Results

The replicator dynamics results are shown in Figures 2 and 3. The proportion of privately insured patients declines rapidly until it reaches the equilibrium proportion of 0.117 using private insurance. The average benefit of using Medicare exceeds the average benefit of using private insurance until they equalize at the proportion of 0.117.

In comparison to the Australian proportion buying private insurance given in Figure 1, the decline in the model is more rapid. The final proportion from the model is also lower than in 1998 for Australia. However, further declines in the proportion of Australians buying private insurance appear likely.

Figure 2: Proportions privately insured and using private hospitals

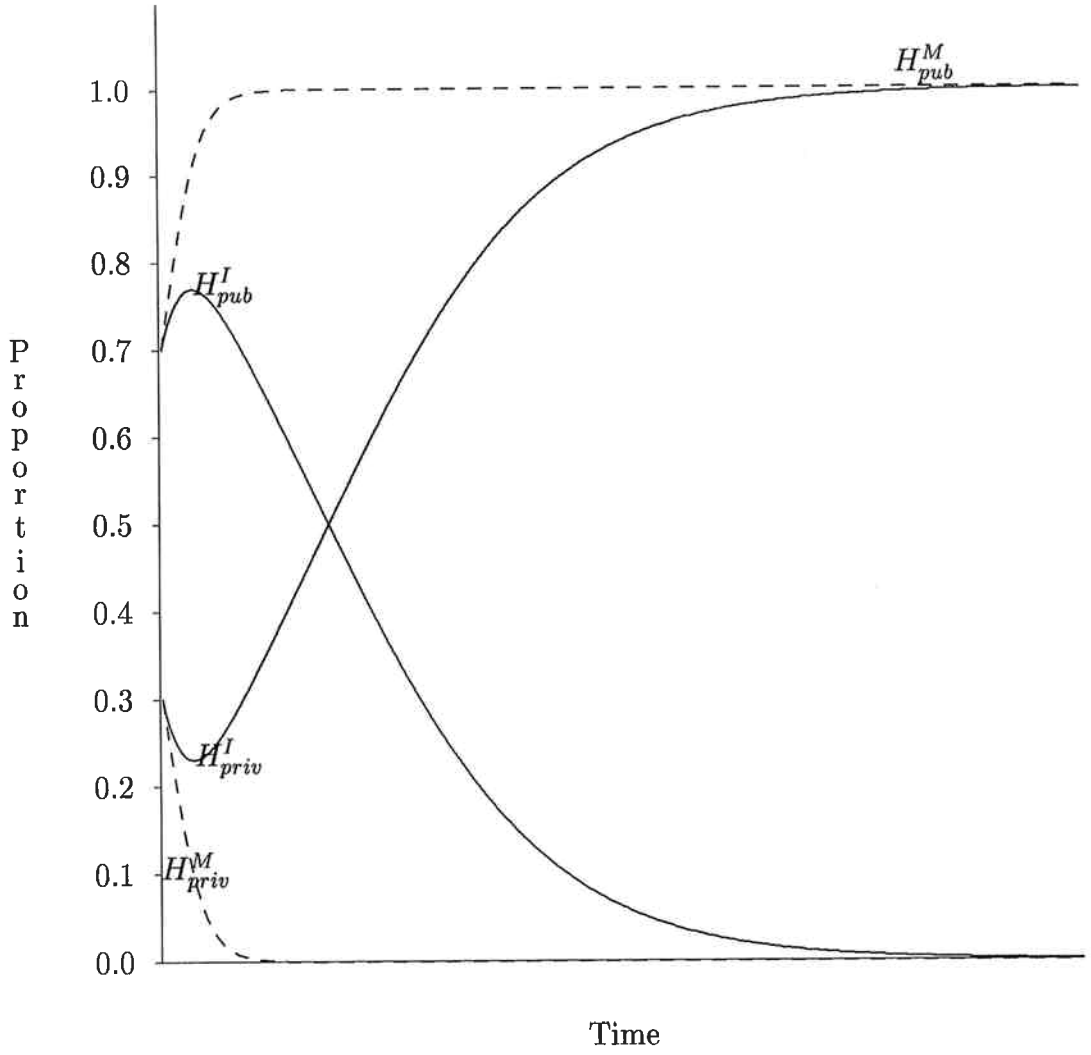


The overall proportion of patients using private hospitals at first declines and then increases slightly. It reaches the same equilibrium proportion as the proportion privately

insured above. The reasons for this are easily seen Figure 3. The proportion of persons using private hospitals that are privately insured at first declines and then increases until it reaches the equilibrium proportion of one. At the beginning of the game, the benefit of using public hospitals is greater than the average overall for insured patients. This is likely due to low congestion at public hospitals. Later, as congestion increases, the benefit of using private hospitals is greater than the average overall for insured patients. Therefore, the insured steadily move towards private hospitals from the inflection point.

The proportion of Medicare patients using private hospitals steadily and quickly declines until it reaches the equilibrium proportion of zero.

Figure 3: Proportion using public and private hospitals from each sub-population



4 Discussion

This paper has modeled the health insurance and health provider sectors using a multi-population replicator dynamics approach. Given the informational problems in health care and given uncertainties of government policy, it is not surprising that the proportion

of people buying private insurance fails to reach an equilibrium quickly. This implies that an approach that utilizes bounded rationality is warranted. At any point in time, the relative benefits of using public hospitals can change due mainly to congestion, or, in a related matter, quality. Demand for private insurance can change over time due to adverse selection. The complementarity of the two markets means that either market can affect the other greatly, accelerating either congestion at public hospitals or adverse selection. The model presented in this paper features endogenous payoffs.

Admittedly, clean policy implications such as those found in traditional welfare economics are not available with this model. However, it is likely that the partial equilibrium approach taken in the literature are not appropriate, rendering those welfare implications less useful. One could examine the equilibrium in the traditional static framework, although this analysis has not done so.

If policy-makers want to change the reliance on the public or private sector, they must consider both the insurance and the provider markets. If they, for instance, offer a rebate for private insurance such as the one offered in this model, they should realize that the demand for private care will increase over time. What's more, if there is a preference for private care which is increasing in "sickness," the rebate will shift the worst cases to the private sector.

Table 1: Parameters and starting values

Parameter	
w	120
P	220
β	0.3
d	30
R	0.3
α	1
c	50
γ	10
a	2
Starting values	
H^I_{priv}	0.3
H^I_{pub}	0.7
H^M_{priv}	0.3
H^M_{pub}	0.7
I	0.68
M	0.32

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