A Model of an Assisted Reproductive Techonology (ART) Market

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During the last twenty-five years, assisted reproductive technologies (ART) such as *in vitro* fertilization (IVF) have emerged as a leading treatment for infertility. An estimated $10\% - 15\%$ of American married couples include a wife of reproductive age who is infertile,[1] and during 2000 approximately 100,000 treatment ART cycles were performed at 405 clinics in the United States. These treatment cycles resulted in 25,000 live births and 35,000 babies.[2]

The difference between the number of births and the number of children born following ART highlights one of the important characteristics of infertility treatment. Multiple births are much more common following medical treatment than occur naturally. This has important economic consequences, since the health risks and medical expenses of multiple births can be substantial.[3] Moreover, not all of these costs are borne by ART clinics and their patients, so choices may be affected by moral hazard.

Another important feature of the ART market is that most patients pay out-of-pocket for their treatment. The full cost of one ART cycle to a patient is typically \$10,000 – \$15,000, with 70% of this expense for clinics' fees and 30% for ovulation drugs. The expected expense of one birth is even higher, as ART patients currently have a success rate of about one-third.[4] However, a small

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[1] Infertility is generally defined as the inability to conceive a pregnancy after 12 months of trying to conceive without contraception (Stephen and Chandra [2000]). Data from the 1995 National Survey of Family Growth indicate that 21% of childless women aged 35-44 have received infertility treatments (Abma, et al. [1997]).

[2] A single event recorded as a "live birth" may be the delivery of twins, triplets, or more. See Reynolds, et al. [2003] for additional details on the relative importance of ART to multiple birth rates in the United States.

[3] Goldfarb, et al. [1996] calculate the mean medical cost of delivering a singleton baby or set of twins to be \$39,000, while the average cost of delivering triplets is \$342,000. Low birthweight children experience more medical problems later in life, and the costs of these problems fall more heavily on parents.

[4] This influenced both by the current state of ART techonogy and the selection of patients who take treatment.

number of states mandate complete or partial insurance coverage of clinics' IVF fees.[5] In the mid-to late-1980s twelve states enacted mandates regarding insurance coverage of ART. These states vary in whether insurers are required to cover ART expenses for all clients or just offer ART coverage for a fee. The states also differ in the number of ART cycles that may be covered, the types of technology that may be used, and the conditions that a patient must satisfy before receiving covered treatment. In 2001 two additional states enacted insurance mandates for infertility treatment.

In this brief paper we consider the factors that affect patients' and clinics' incentives in an ART market. We focus on three central issues: 1) How does a couple choose the timing of their ART treatment? 2) How does insurance affect access to ART, clinics' technology choices, and patients' multiple birth risks? 3) Can competition improve access to ART in a way similar to insurance? Our approach here is use a simple dynamic model of (potential) patients' reproductive choices and clinics' pricing and technology decisions. The intuition we gain from the model is applied to data in a related paper (Hamilton and McManus [2003]).

1 Preferences and Fertility Technology

Assume that the market for ART is populated by overlapping generations of 'young' (Y) and 'old' (O) couples. There are N couples of each type in the market during every period. Couples want to reproduce once (bear one child), and they have two periods of reproductive life in which to do this. Each couple is endowed with a fertility parameter t and a stock of assets, A. We assume that the distributions of these endowments are independent, and $t \sim U[0, \gamma]$ and $A \sim U[\underline{A}, \overline{A}]$.[6] The parameter γ is in $(0,1)$ While a couple is young, their chance of having a child without ART is t.[7] As the couple ages, their fertility reduces by the factor $\theta \in (0,1)$ and their chance of having a child naturally is θt. If the couple is successful in conceiving a child while young, they make no reproductive decisions while old. We assume that there is a delay of one period after conception until a child is born. The present value of lifetime utility from a child is B for every couple in the market. There is no discounting of future utility, so the present value of conceiving a child while young (and bearing it while old) is B, as is the present value to the young of a child conceived while old.

[5] Drug expenses are generally excluded from insurance coverage.

[6] The distributional assumptions on t and A do not affect couples' choices, and only matter in the numerical examples of Section 3.

[7] Think of γ as the maximal (but still imperfect) fertility of a young couple.

Couples can increase their chance of conception by using a monopoly ART clinic's treatment services.[8] Each couple and the clinic have perfect information about a couple's innate fertility. When the clinic employs the technology $k > 1$, it provides a conception probability of $\phi(t, k)$ to a young couple. Birth probabilities are scaled down by θ for old couples. We parameterize ϕ as $\phi(t, k) = \gamma kt$ for $t \leq 1/k$ and $\phi(t, k) = \gamma$ for $t > 1/k$. The advantage of this functional form is that higher k implies (weakly) higher birth probabilities; this is illustrated on Figure 1. Additionally, $\phi(0, k) = 0$ and $\phi(1, k) = \gamma$, so very low and very high fertility couples do not gain much from using the clinic's services. The clinic collects a price of p for each use of its fertility services, and couples pay the additional fee d (for drugs and other expenses) when they use ART. Let $x = p + d$ be the full expense of one ART treatment to a couple. We assume that the ART clinic uses the same technology in treating all of its patients, and all patients are charged the same price.

Couples pay x out of their asset endowment. Each couples decides how to divide its assets among composite goods and ART services during periods Y and O. The composite good, c, is available at a price of one during each period, and the interest rate for saving and borrowing is zero. The utility of consuming c^Y while young is $u(c^Y)$, and the utility from c^O while old is $u(c^O)$. We assume that all couples share the same utility function. The continuous and twice-differentiable utility function $u : \Re^+ \to \Re$ has $u' > 0$, $u'' < 0$, $\lim_{c\to\infty} u(c) = \overline{u} < \infty$, and satisfies the Inada conditions $\lim_{c\to 0} u'(c) = -\infty$ and $\lim_{c\to\infty} u'(c) = 0$. Spending on the composite goods and infertility treatment must satisfy the intertemporal budget constraint $c^Y + 1(Y)x + c^O + 1(O)x \leq A$. $1(\tau)$ is an indicator function that equals one when the couple uses ART during period τ (and zero otherwise). A couple's expenditure on ART may be reduced by insurance coverage. We model insurance as the opportunity to use ART once while paying only d. A couple with insurance may choose to use ART during both Y and O, but they must pay $p + d$ out-of-pocket during one of the periods.

2 Value functions and demand

We describe the couples' utility and demand in the market by working backwards through their choice problems. Suppose a couple did not receive ART treatment while young. The couple has assets of $c = (A - c^Y)$ remaining to split between c^O and ART treatment during O. With

[8] Couples in this model have only one interaction with a clinic during an attempt at reproduction, so we use the terms "treatment" and "cycle" interchangeably in this section.

probability t the couple conceived a child while young, and they enter O as their child is born. In this case, $c^O = c$ and their utility is $B + u(c^O)$. However, with probability $(1-t)$ the couple does not bear a child at the beginning of O, and they must decide whether to use ART during this period. If they do not use ART, their expected utility is $N^O(c|A,t) = B\theta t + u(c)$. The expected utility to this couple from ART is $T^O(c|A,t) = B\theta\phi(t,k) + u(c-x)$. ($N$ indicates "no treatment," and T indicates "treatment.") The couple chooses the larger of these two expected payoffs. We define $V^O(N, c^Y|A,t)$ to be the value function to the old of selecting c^Y and not choosing ART while young, conditional on initial assets and innate fertility. We combine the payoffs above to get

$$V^O(N, c^Y|A,t) = t[B + u(c^O)] + (1-t)\max\{N^O(c|A,t), T^O(c|A,t)\}. \tag{1}$$

The value function to the young from not receiving treatment while young is $V^Y(N, c^Y|A,t)$, and it is simply

$$V^Y(N, c^Y|A,t) = u(c^Y) + V^O(N, c^Y|A,t).$$

The value functions for couples who choose treatment while young are very similar. Couples who receive ART while young have N^O and T^O of the same form as above, but their consumption possibilities are affected by their earlier infertility treatment decision. These couples enter period O with $c = (A - c^Y - x)$ remaining. The other difference is that the chance of entering O as a child is born is now $\phi(t,k)$ instead of t; the probability of not having a child adjusted accordingly. Thus, the value function of the old who choose ART and c^Y while young is

$$V^O(T, c^Y|A,t) = \phi(t,k)[B + u(c^O)] + (1-\phi(t,k))\max\{N^O(c|A,t), T^O(c|A,t)\}.$$

The value function for the same couples while young is

$$V^Y(T, c^Y|A,t) = u(c^Y) + V^O(T, c^Y|A,t).$$

For each period-Y reproductive choice, couples solve for an optimal choice of c^Y. These different c^Y values are plugged into $V^Y(T\cdot)$ and $V^Y(N\cdot)$, and the couple compares the V^Y's to start its sequence of consumption and reproduction choices. On Figure 2 we illustrate how different levels of t lead to different treatment choices in this model. To simplify notation on the figure, we consider the static decision of treatment during O when $\gamma = \theta = 1$ and c is (suboptimally) constant in t.

What leads different couples to choose different fertility treatment paths? The couples who benefit from ART the most are those who: (1) have values of t that permit a large increase in their conception chances through treatment, and (2) have sufficiently high assets so that the utility loss from foregone consumption is not too large. These effects are easiest to see in the choice of an old couple who did not conceive while young. The $\max\{N^O, T^O\}$ component of the value function may be rearranged to equal

$$u(c) + B\theta t + \max\{B\theta[\phi(t,k) - t] - \Delta(c), 0\}. \tag{2}$$

$\Delta(c) = [u(c) - u(c-x)]$ is the price that the couple must pay in lost utility from consumption in exchange for the fertility gain $(\phi - t)$ from ART. Couples who take ART treatment during O have values of t in $[t_1, t_2]$, with these thresholds defined by the conditions

$$t_1 = \frac{\Delta(c)}{B\theta(k-1)} \quad \text{and} \quad t_2 = 1 - \frac{\Delta(c)}{B\theta}.$$

The set of fertility types who choose treatment expands with k and contracts with x (through Δ), holding c fixed. If we increase c (to represent a larger store of assets brought into O) the concavity of u increases the fertility range of those who seek treatment, holding k and x fixed. The conditions that identify which couples receive treatment during Y are similar, but dynamic considerations and differences in c^Y between treatment options prevent us from providing closed-form expressions for thresholds on t or A.

Next, we briefly describe how choices of c^Y are affected by fertility treatment. If ART treatment was unavailable in the market, the lifetime utility of a couple would be $u(c^Y) + u(c^O)$, and they would maximize this subject to the budget constraint $c^Y + c^O = A$. This yields a familiar solution for c^Y according to $u'(c^Y) = u'(A - c^Y)$. This condition also describes how couples who are "far" in their A and t values from considering treatment solve their intertemporal consumption problem. Conditional on a period-Y treatment choice, couples with A and t who ultimately choose ART faces an additional "expense" in lost utility during O if they increase c^Y. These couples must consider the effect of increasing c^Y on both $u(c^O)$ and $\Delta(c)$.[9] Thus, for a fixed value of A, couples with intermediate values of t (who gain the most from ART during O) choose relatively low values of c^Y as they begin Y with either treatment option.

[9] For couples who forego treatment while young, combine (1) and (2) to obtain

$$\widetilde{V}^O(c^Y) = u(c) + (1 - \gamma t)\max\{z_1 - \Delta(c,x), 0\} + z_2.$$

z_1 and z_2 replace expressions that are unaffected by c^Y, and $c = (A - c^Y)$. The lifetime expected utility $u(c^Y) + \widetilde{V}^O(c^Y)$ is continuous in c^Y and has an interior optimum which is guaranteed by our assumptions on u. However, the marginal utility of c^Y during Y jumps as a couple's choice from the $\max\{\cdot\}$ term changes. $z_1 - \Delta(c,x)$ is strictly concave and decreasing in c^Y, and z_1 is proportional to $\phi(t,k) - t$.

We offer Figure 3 to illustrate the effect of A and t on reproductive choices. Figure 3a covers the situation in which couples make all treatment payments out-of-pocket. Figure 3b illustrates the effect of insurance, which is discussed below. The labels $\{N, N\}$, $\{N, T\}$, $\{T, N\}$, and $\{T, T\}$ indicate choice paths along which a couple chooses to use ART during neither Y nor O, or no treatment during Y but ART during O, etc. The size of the $\{N, T\}$ and $\{T, T\}$ regions indicate how many couples would be *willing* to buy ART treatment while old, but some of these couples do not make this choice because of a pregnancy during Y. If we pick an arbitrary t near the center of the horizontal axis on Figure 3a, we observe that as A increases couples will move from choosing zero, to one, to two treatments. As assets increase, the utility loss from x falls and ART feels less expensive. This means that in higher-wealth markets, more old patients will receive treatment for the second time, and selection effects on treatment success will lower the innate fertility of the remaining patients. The relative positions of the $\{N, T\}$ and $\{T, T\}$ regions may be different from what is displayed on the figure for some combinations of parameter values. The current positions of the regions are driven by higher-t couples having a better chance of conceiving naturally during Y, and therefore it is less costly in terms of foregone reproductive opportunities for such a couple to refuse ART while young.

3 Numerical examples, extensions, and empirical implications

3.1 Assumptions on demand parameters and clinics' objectives

We solve several numerical examples to illustrate which factors in the model above are most important in generating activity in the ART market. Unless we note otherwise, all examples are solved under the demand parameter values provided on Table 1. We assume that ART clinics maximize profit by choosing p and k. p is selected from $\Re^{+}$, and we restrict k to the set $\{1.0, 1.1, 1.2, ..., \overline{k}\}$. Clinics make myopic choices of p and k, only looking at the current demand of the young and old couples during the present period. If we write $D(p, k)$ for demand, profit has the form $D(p, k)[p - c(k)] - F(k)$. The marginal cost of an additional treatment is independent of quantity, but both variable and fixed costs depend on k. We assume that c and F are increasing and strictly convex functions of k. The functional form of marginal cost is $c(k) = m_1 + m_2(k-1)^2$, and fixed cost is $F(k) = f_1 + f_2(k-1)^2$. The parameter values for the m's and f's are also on Table 1.

3.2 Introducing insurance

The treatment choice model requires only one minor change to accommodate the case of one-time insurance coverage. In our model, insurance coverage means that a couple who uses insurance bears the expense $x = d$, while a couple who does not pays $x = p + d$. We do not restrict the timing of insurance payments – it is possible to pay $p+d$ out-of-pocket during Y and then pay d for treatment during O – but it is never optimal to delay using insurance when it is available.[10] The clinic's objective function is affected because not all of its patients pay for ART out-of-pocket. When there is an insurance mandate, we write the profit function as $D^U(p,k)[p - c(k)] + D^I(p,k)\rho - F(k)$. D^U and D^I are demand from uninsured and insured couples, respectively, and ρ is the reimbursed margin paid by an insurance firm to the clinic.[11] We assume that $\rho = \$1,000$, which is selected because it is small relative to the margin taken on uninsured patients.[12]

Insurance has both an immediate price effect and an intertemporal income effect. The price effect is the simple reduction in the relative price of treatment (now d) compared to the zero-price option of no treatment. The income effect increases the chance of treatment during O for couples who have paid a low price for ART during Y, and therefore have a larger stock of assets as they begin O. This is exactly the effect of an increase in c on $u(c) - u(c - x)$ discussed above.

We calculate the optimal p and k for a monopoly clinic in markets with and without insurance. The results of these calculations are reported on Table 2. There are two important effects to notice. First, introducing insurance leads to a substantial increase in the number of couples served by the clinic, with the demand increase proportionally larger among the young. This is apparent when we compare Figures 3a and 3b. The reduction in x means the most to people with low assets because of the concavity of u. These couples were closer to the never- v. once-treated margin rather than the once- v. twice-treated margin, so the introduction of insurance leads to a large increase in

[10] If a couple did delay using insurance while taking treatment during Y, it is possible that the couple would conceive on their first try and leave their insurance coverage on the table. Note that there still may be couples who use insurance coverage during O, but only if they have elected to forego treatment while young.

[11] There is an important strategic implication of this reimbursement specification. By specifying ρ as the reimbursed *margin* instead of the reimbursed *price*, we allow the full insurance reimbursement to increase with k. This creates an incentive for a clinic to increase k, because the direct effect of additional k on marginal cost is fully reimbursed. If we specify the reimbursed margin as $\overline{\rho} - c(k)$, with $\overline{\rho}$ unaffected by k, the regulated monopolist's incentive to reduce k is even stronger than reported below.

[12] We base this assumption of a "small" reimbursed margin on anecdotes from within the ART industry. The rationale is that insurance firms have relatively strong bargaining power to negotiate a favorable treatment price for its clients.

one-time ART patients. Among the couples who will take treatment once, the benefit of waiting until O is the possibility of conceiving during Y and not needing to pay $p + d$ later. With the expense of one treatment reduced, the benefit of delaying payment falls and couples move their one shot at ART into Y. The second main effect of introducing insurance is the reduction in the clinic's optimal k. This occurs because the clinic does not receive its full price-cost margin from first-time (insured) patients. In order to create full-price patients, the clinic must fail at treating young couples who may return during O. Naturally, the way to create unsuccessful patient cycles is to reduce treatment quality.

Two other features of these numerical examples are worth noting. Success rates are higher among the young because treatment occurs during a more fertile time of life, but the initial innate fertility of old first-time patients is higher than the fertility of young couples who receive treatment. This result is independent of the insurance regime in the market. Also, the average fertility of older patients is higher with insurance because the market is expanded to include more high-fertility couples, but the reduction in k ultimately reduces average success rates despite the favorable selection of patients.

3.3 Embryo choice and multiple births

One of the most important policy issues related to ART is the incidence of multiple pregnancies and multiple births. We incorporate this issue into our model as follows. Suppose that each couple receiving ART treatment can choose to take one or two embryos. The single-embryo situation does not change our description above of ART. If a couple takes two embryos, they experience an increase in the probability of a birth event (singleton or twins) as if the clinic's technology increased from k to k'. However, the couple also bears the risk that two embryos will yield twins. We assume that couples with twins receive the lifetime utility of $(1 - \delta_1)B$ from twins because of additional expenses and health risks. The chance of having twins, conditional on two embryos transferred, is $\delta_2 kt$. Thus the probability of a singleton birth following the transfer of two embryos is $[\phi(t, k') - \delta_2 kt]$.[13] We assume that the clinic charges the same price p to couples who take different numbers of embryos, and we parameterize the difference between k' and k as $k' = \alpha k$ $(\alpha > 1)$.

Embryo choice changes the reproduction action space from $\{N, T\} \times \{N, T\}$ to $\{0, 1, 2\} \times \{0, 1, 2\}$,

[13] In order for two embryos to ever be worthwhile, we require.$k' > \alpha\delta k$.

where the numbers indicate the number of embryos transferred.[14] Again, it is easiest to start with old couples and work backwards. If a couple with c in remaining assets needs to make a reproductive choice during O, the expected payoffs for each treatment option are

$$\begin{aligned} 0^O(c|A,t) &= B\theta t + u(c) \\ 1^O(c|A,t) &= B\theta\phi(t,k) + u(c-x) \\ 2^O(c|A,t) &= B\theta[\phi(t,k') - \delta_1\delta_2 kt] + u(c-x), \end{aligned}$$

with $j^O(\cdot)$ indicating the number of embryos. The expression $\max\{0^O(c|A,t), 1^O(c|A,t), 2^O(c|A,t)\}$ enters the couple's value function during O regardless of their period-Y choices. Low fertility couples gain the most from $\phi(t,k')$ and have the lowest probability of bearing twins, and they take two embryos. Higher fertility couples take one embryo. As above, the chance that a couple enters O with a child after foregoing treatment during Y is t, and the chance for a child conditional on one embryo during Y is $\phi(t,k)$. If a couple takes two embryos during Y, they have at least one child with probability $\phi(t,k')$, and twins with probability $\delta_2 kt$. Combining these probabilities with the unconditional utility values of one and two children, we obtain an expected payoff of $B[\phi(t,k') - \delta_1\delta_2 kt]$. The value functions to old couples from the three treatment options they might have taken while young are:

$$\begin{aligned} V^O(0,c^Y|A,t) &= t[B + u(c^O)] + (1-t)\max\{\cdot\} \\ V^O(1,c^Y|A,t) &= \phi(t,k)[B + u(c^O)] + (1-\phi(t,k))\max\{\cdot\} \\ V^O(2,c^Y|A,t) &= \phi(t,k')u(c^O) + B[\phi(t,k') - \alpha\delta kt] + (1-\phi(t,k'))\max\{\cdot\}. \end{aligned}$$

The function $V^O(j,c^Y|A,t)$ is the value of taking j embryos while young. $\max\{\cdot\}$ represents $\max\{0^O(c|A,t), 1^O(c|A,t), 2^O(c|A,t)\}$ in each $V^O(j,c^Y|A,t)$. The value functions for young couples are again simply $V^Y(j,c^Y|A,t) = u(c^Y) + V^O(j,c^Y|A,t)$.

A prominent conjecture in the medical literature regarding the effect of insurance on embryo choice (*e.g.*, Jain et al. [2002]) is that insurance reduces the incentive for couples to request a high number of embryos. A couple may take a high number of embryos to maximize the chance of having a child on the current ART cycle, because they cannot afford to pay for ART again in the future. Insurance coverage reduces this incentive through the intertemporal income effect. This is

[14] An important difference between our model and actual ART treatment is that less fertile couples may have difficulty in obtaining (potentially) viable embryos. That is, the option to transfer a high number of embryos is more frequently available to high-fertility patients.

intuitively appealing, but in our model this income effect is small relative to the direct price effect of insurance coverage on new patients. See Figure 4 for how embryo choices and timing vary with A and t. As in Figure 3, we present separate illustrations for choices without (Figure 4a) and with (Figure 4b) insurance. The income effect of insurance on embryo choice matters to people who take 2 embryos once because they cannot afford to take one embryo twice. However, Figure 4a shows that there are not many couples who choose two embryos and then zero (or zero and then two), and are adjacent to a region in which couples take one embryo. If the measure of couples on the margin relevant to the income effect is small, the effect of insurance on these couples is likely to be swamped by the large number of people who enter the market because of insurance's price effect.

We solve for the optimal monopoly p and k with and without insurance in a numerical example to illustrate these effects. Additionally, we solve for the optimal p under insurance when k is fixed at the unregulated optimum. Results are reported in Table 3. Two main features of this example are similar to the case of insurance without embryo choice. First, the reduced price of treatment greatly increases the number of couples who use ART. Second, the clinic reduces k in order to increase the population of full-price (second-time) patients. We note that the effects of insurance on embryo choice are opposite in the case of optimal and fixed k. Despite the intuition regarding the income effect of insurance on embryos, we find that the clinic's reduction in k following an insurance mandate leads to an increase in the average number of embryos. With a lower technology level, the risk of twins is reduced and couples are more willing to take an additional embryo for the increase in birth probability. This is apparent in the relatively small changes in overall birth rates and twin risk between the cases of: 1) unregulated monopoly, and 2) optimal p and k under an insurance mandate. Finally, we note that despite small changes in the risk of twins due to insurance in our examples, the total number of twins increases substantially with insurance. Even when couples make embryo choices that are "safer" under insurance, the influx of new patients can lead to an increase in the total number of multiple births.[15]

[15] We should stress that the high medical expense of multiple births does not mean that there are too many of them. Such a statement would require data and theory on the benefits and costs of all treatment options, and this is beyond the scope of the present research.

3.4 Multiple ART clinics

In our final numerical exercise, we examine the effect of competition on the ART market. We consider a duopoly situation in which clinics simultaneously select k values, observe each other's technology, and then simultaneously choose prices. In equilibrium the market is a vertically differentiated duopoly, with low-fertility couples choosing the higher-k clinic. Suppose clinics H and L select values of k and p such that $k_H > k_L$ and $p_H > p_L$. Then the clinics' technologies increase birth probabilities according to $\phi(t, k_H)$ and $\phi(t, k_L)$. The value functions of couples are very similar to those described above in the embryo choice model. If N (no treatment), H (high-k clinic), and L (low-k clinic) are the three possible choices for a couple during O, the expected payoffs from the options are:

$$\begin{aligned} N^O(c|A,t) &= B\theta t + u(c) \\ H^O(c|A,t) &= B\theta\phi(t,k_H) + u(c - p_H - d) \\ L^O(c|A,t) &= B\theta\phi(t,k_L) + u(c - p_L - d). \end{aligned}$$

See Figure 5 for an illustration of how old couples of varying t and fixed A separate across the treatment options in the notationally simple case of $\gamma = \theta = 1$ and c constant in t. A couple that enters period O without a child selects the best option from $\{N, H, L\}$; that is, they receive $\max\{N^O(c|A,t), H^O(c|A,t), L^O(c|A,t)\}$. As in the embryo choice model, the value functions of old couples, depend on period-Y choices and are written

$$\begin{aligned} V^O(N, c^Y|A,t) &= t[B + u(c^O)] + (1-t)\max\{\cdot\} \\ V^O(H, c^Y|A,t) &= \phi(t,k_H)[B + u(c^O)] + (1-\phi(t,k_H))\max\{\cdot\} \\ V^O(L, c^Y|A,t) &= \phi(t,k_H)[B + u(c^O)] + (1-\phi(t,k_L))\max\{\cdot\}, \end{aligned}$$

where $V^O(j, c^Y|A,t)$ is the value while old of choosing $j \in \{N, H, L\}$ while young. The value functions of young couples are $V^Y(j, c^Y|A,t) = u(c^Y) + V^O(j, c^Y|A,t)$, $j \in \{N, H, L\}$.

Clinics are ex-ante symmetric with respect to costs, but the equilibrium cost functions diverge as the clinics select different values of k. We assume the same cost function for the clinics as in the previous numerical examples. Let $\mathbf{p} = (p_H, p_L)$ and $\mathbf{k} = (k_H, k_L)$, and write the profit to clinic j as $D_j(\mathbf{p}, \mathbf{k})(p_j - c(k_j)) - F(k_j)$. Our procedure for solving the numerical model is to take each possible combination of k values, and then solve for the equilibrium prices and calculate profit for each clinic conditional on the technology levels. We then search over the profit levels for each $\mathbf{k}$ to construct best-response functions in k, and find the equilibrium technology choices.[16] We do not consider the effect of insurance on competition because the data show that insurance mandates are generally associated with low levels of competition.[17]

The results of our numerical exercise are reported in Table 4. We reproduce the unregulated monopoly outcomes from Table 2 for comparison. As expected, treatment is offered at lower prices under competition than monopoly, and this substantially increases the number of couples served. The incentive for the clinics to differentiate their treatment is apparent in their equilibrium choices of k – one is below and the other is above the monopoly technology level. Although one duopolist selects a value of k above the monopoly k, the cohort of couples that go to this clinic yield a lower success rate than under monopoly. Similarly, the low-technology clinic has higher success rates than its competitor because of selection effects.

4 Discussion

In this brief paper we have examined some important factors that affect markets for ART. The main results are:

- An insurance mandate can encourage couples to take ART treatment earlier, as well as bringing more couples into the ART market;
- Insurance, coupled with low reimbursement rates from insurers, can cause clinics to adopt relatively low ART technology;
- The income effect of insurance on embryo choice may be small relative to the price effect that brings new patients into the ART market; and

[16] We restrict are search to pure strategy equilibria in which the clinics choose different values of k. Conditional on this criterion, we found a unique equilibrium for each combination of the parameter values that we employed. In general, there must be at least three equilibria in the k-selection game, since the identies of the clinics (one is high-k and which one is low) could switch or the clinics could play mixed strategies.

[17] There are two possible explanations for this phenomenom. First, when insurance companies must offer ART coverage, there is an incentive to identify a single clinic to which all insurance clients are directed. The insurance company may hold a procurement auction, and the winning clinic (which receives the insurer's clients) offers the lowest reimbursement rate. Bids would be more aggressive in a situation with one rather than two auction winners. (This also would explain why ρ is relatively low.) Second, it may be the case that insurance forecloses competition in a more directly endogenous way. If couples may choose among several clinics freely and always pay the same expense d, they will always favor the highest-technology clinic. Low-k clinics will not survive in the market.

- Competition can bring new patients into the ART market in a way similar to an insurance mandate, and clinics' incentives to vertically differentiate can result in a wider variety of clinic technology levels.

  In our companion paper, Hamilton and McManus [2003], we test these predictions using clinic-level data from ART markets.

References

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TABLE 1

Parameter Values for the Numerical Model

Utility	Misc. Demand	Fertility	Technolgy and Costs
B = \$20,000	N = 20,000	γ = 0.6	$\bar{k}$ = 5.0
u(c) = ln(c/1000)	$\underline{A}$ = \$30,000	θ = 0.8	m_1 = \$2,000
δ_1 = 0.25	$\bar{A}$ = \$150,000	δ_2 = 0.5	m_2 = \$2,000
D = \$5,000		α = 1.4	f_1 = \$5,000,000
			f_2 = \$5,000,000

TABLE 2

Monopoly ART Clinic, with and without Insurance

	No Insurance	Insurance
p	\$11,347	\$9,649
k	2.1	1.9
Young Couples		
# Cycles	3,635	10,434
Success rate	0.51	0.47
Avg. Fertility (t)	0.45	0.48
Avg. Assets (A)	\$120,900	\$99,167
Old Couples		
# Cycles	1,661	4,084
Success rate	0.41	0.35
Avg. Fertility (t)	0.47	0.46
Avg. Assets (A)	\$124,122	\$104,000

TABLE 3

Embryo Choice and Monopoly Clinics, with and without Insurance

	No Insurance	Insurance	
		Optimal *k*	*k* fixed at 2.0
p	\$12,112	\$6,462	\$8,167
k	2.0	1.7	2.0
Young Couples			
# Cycles	4,153	6,589	6,523
Success rate	0.52	0.50	0.51
Avg. Fertility (*t*)	0.41	0.45	0.42
Avg. Assets (*A*)	\$120,016	\$113,468	\$113,365
Avg. # Embryos	1.544	1.567	1.506
% Cycles with Twins	0.101	0.098	0.090
# Twins	419	647	586
Old Couples			
# Cycles	2,290	3,947	3,609
Success rate	0.43	0.40	0.41
Avg. Fertility (*t*)	0.43	0.45	0.43
Avg. Assets (*A*)	\$121,537	\$112,713	\$113,977
Avg. # Embryos	1.495	1.551	1.477
% Cycles with Twins	0.083	0.085	0.076
# Twins	190	337	274

TABLE 4

Duopoly Clinics v. Monopoly Clinic

	Duopoly		Monopoly
	Clinic 1	Clinic 2	
p	\$9,745	\$7,055	\$11,286
k	2.2	1.7	2.1
Young Couples			
# Cycles	3,327	2,730	3,664
Success rate	0.49	0.51	0.51
Avg. Fertility (*t*)	0.41	0.54	0.45
Avg. Assets (*A*)	\$116,473	\$114,285	\$120,835
Old Couples			
# Cycles	1,659	1,580	1,592
Success rate	0.39	0.41	0.42
Avg. Fertility (*t*)	0.41	0.54	0.47
Avg. Assets (*A*)	\$118,801	\$113,825	\$124,448

FIGURE 1

Fertility-Enhancing Technology

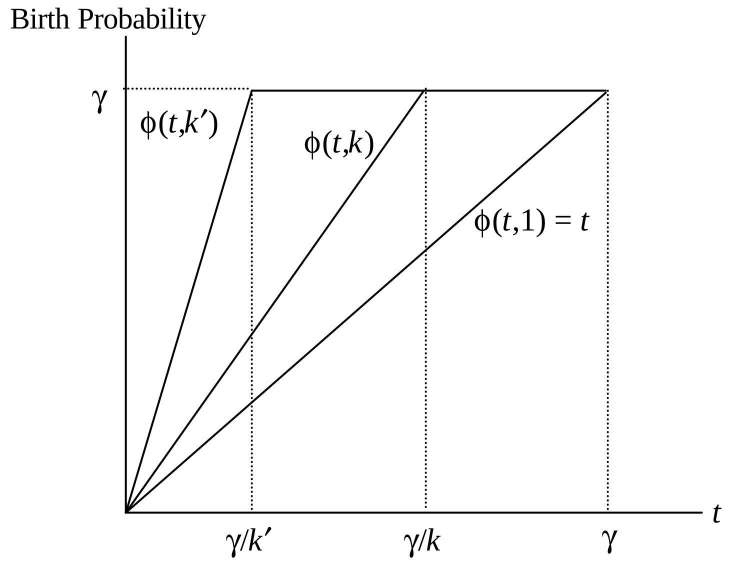
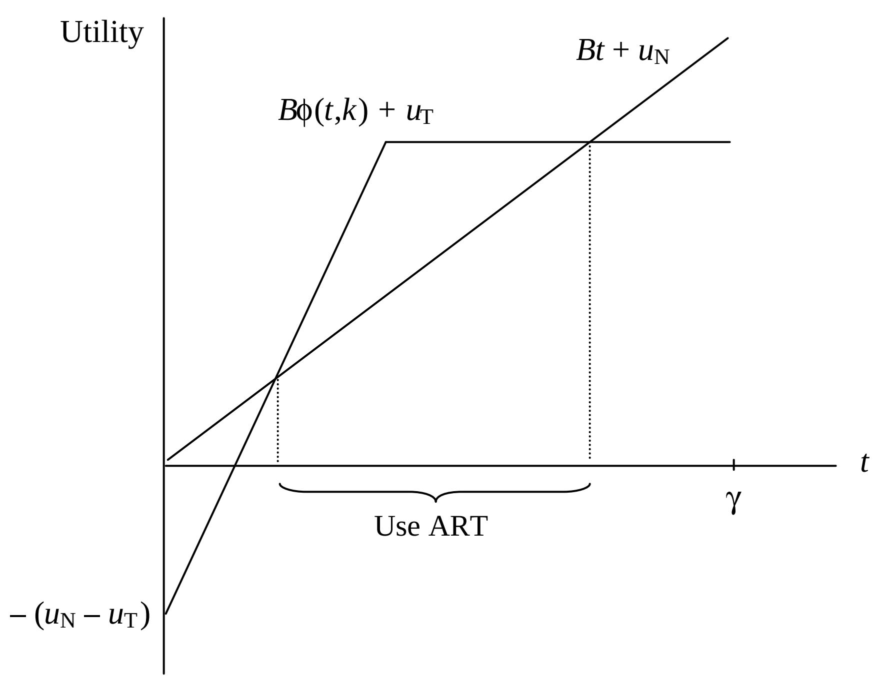


FIGURE 2

Treatment Choice under Monopoly as *t* Varies



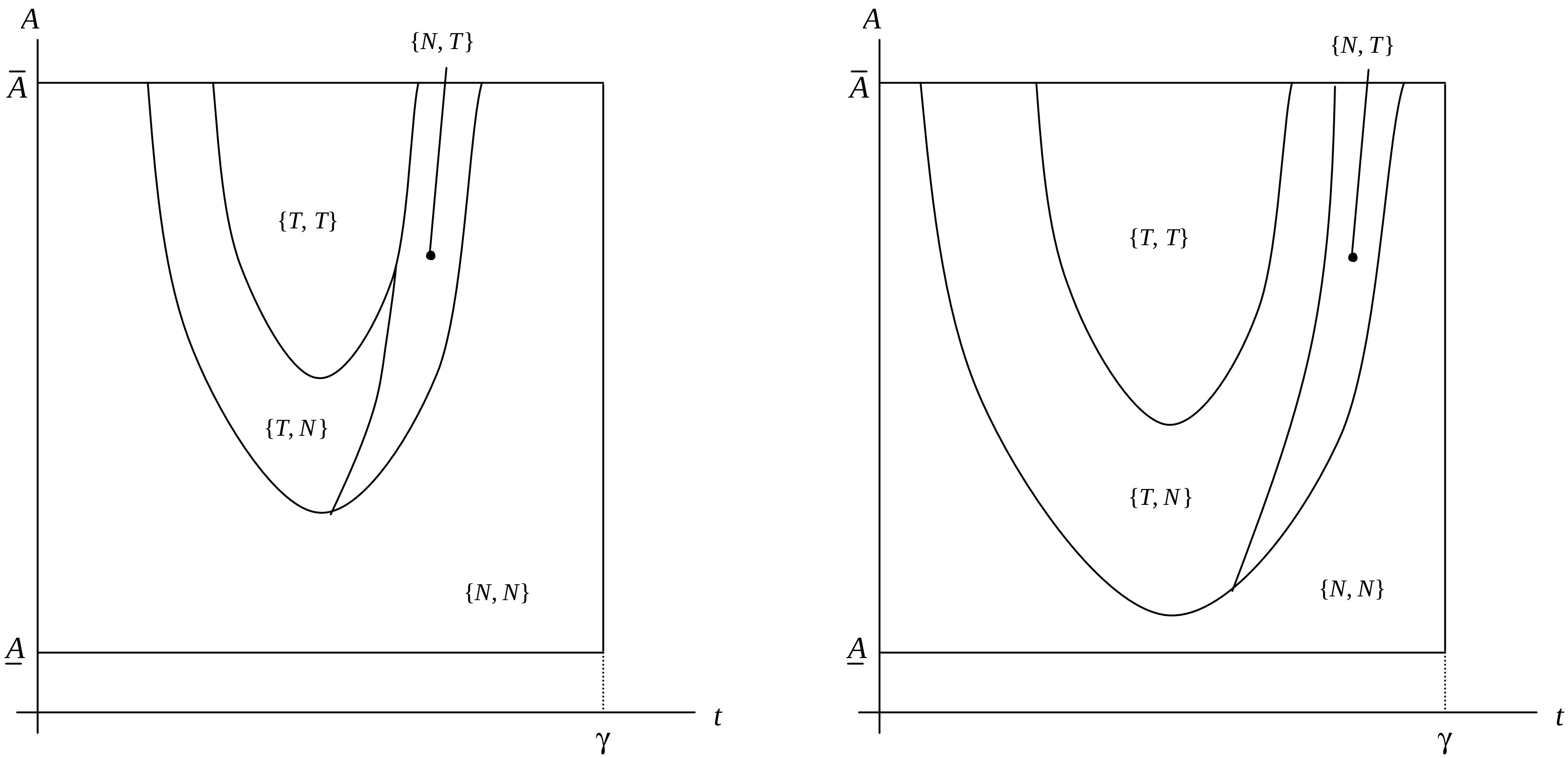
Possible actions are to take treatment (*T*) or not (*N*). Couples choose the action that provides the highest utility. **Notation:** $u_N = u(c)$, $u_T = u(c - p - d)$. $u_N > u_T$.

FIGURE 3

Partition of (A, t) Types into Choice Paths under Monopoly

Fig. 3a: Couples' choices without insurance

Fig. 3b: Couples' choices with insurance



Possible actions are ART treatment (T) and no treatment (N). A pair $\{i, j\}$ indicates action i during Y and action j during O, conditional on reaching O without a child. The relative sizes and positions of the choice regions are consistent with the parameter values from Table 1 and the optimal p and k values on Table 2.

FIGURE 4

Partition of (*A*, *t*) Types into Embryos Transfer Choices

Fig. 4a: Couples' choices <u>without</u> insurance

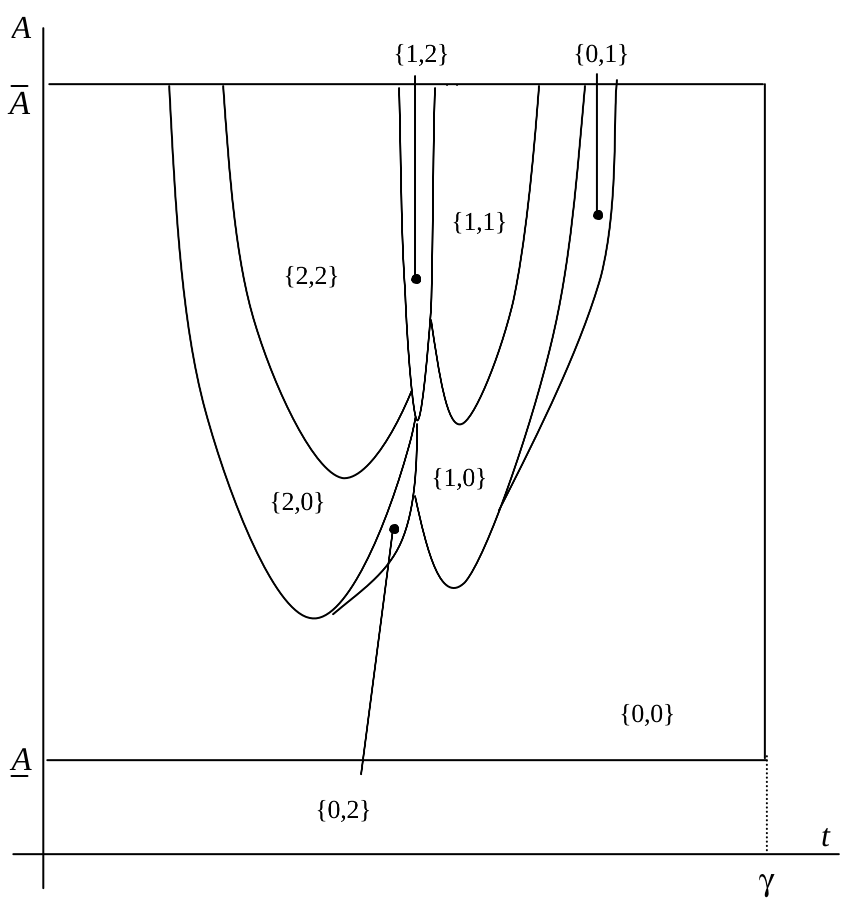
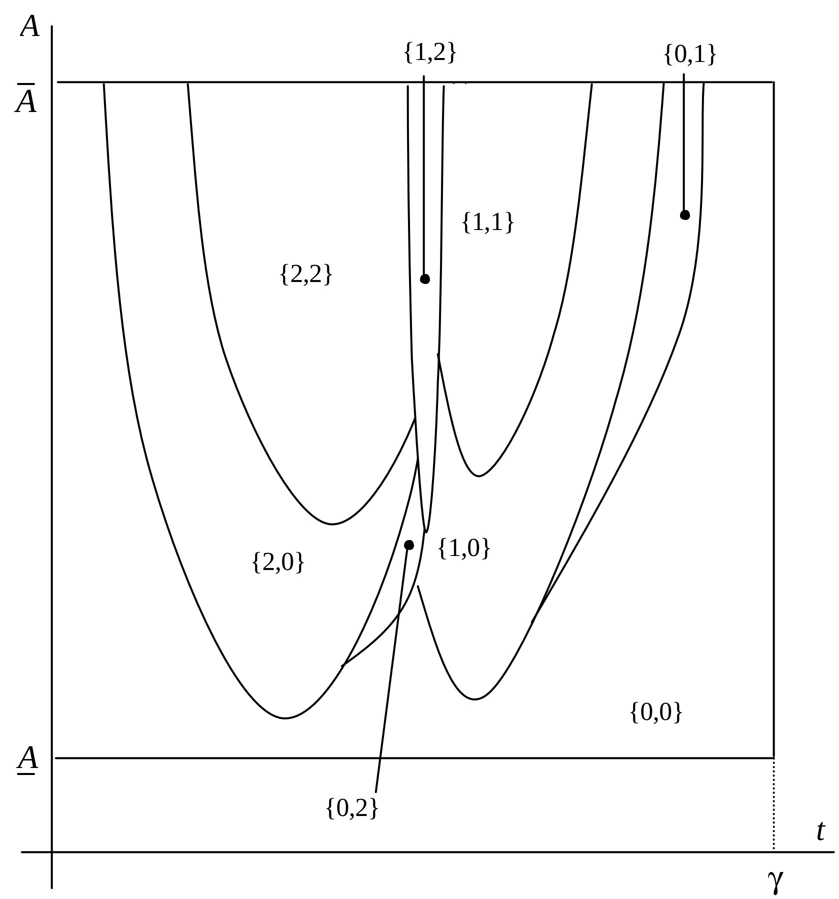


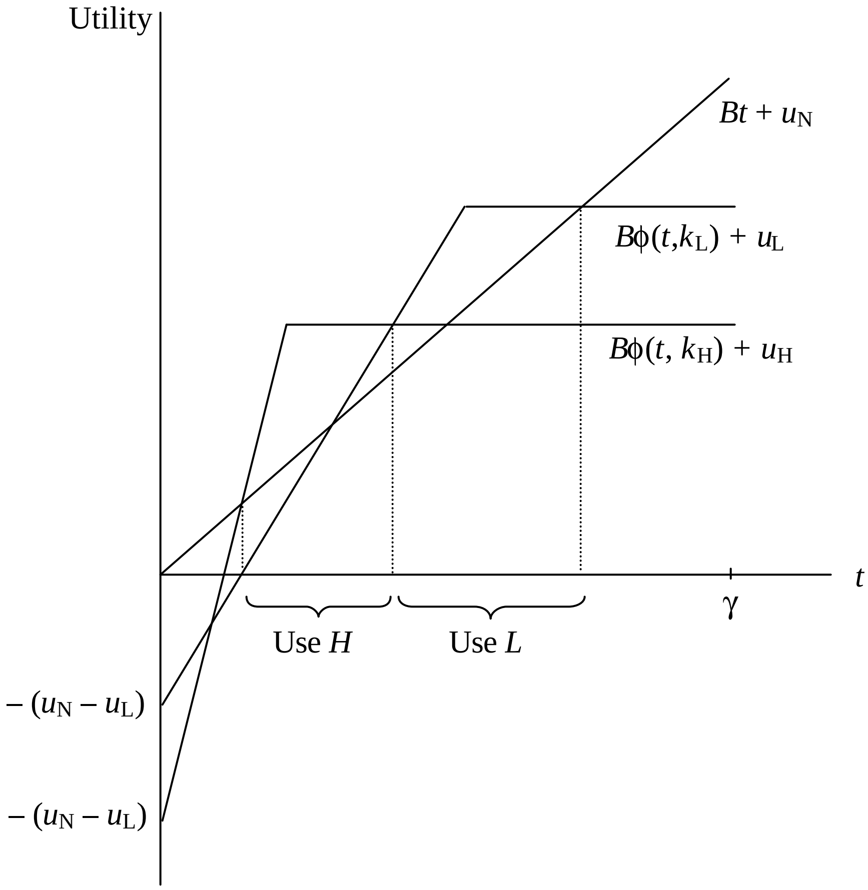
Fig. 4b: Couples' choices <u>with</u> insurance



Possible actions are 0, 1, or 2 embryos. (0 is the same as the choice "no treatment.") A pair $\{i, j\}$ indicates *i* embryos during *Y* and *j* embryos during *O*, conditional on reaching *O* without a child. The relative sizes and positions of the choice regions are consistent with the parameter values from Table 1 and the optimal *p* and *k* values on Table 3.

FIGURE 5

Treatment Choices under Duopoly as t Varies



Possible actions are to take no treatment (*N*), use the high-technology clinic (*H*), or use the low-technology clinic (*L*). Couples choose the action that provides the highest utility. **Notation:** $u_N = u(c)$, $u_L = u(c - p_L - d)$, $u_H = u(c - p_H - d)$. $u_N > u_N > u_N$ when $p_H > p_L > 0$.