HERD BEHAVIOR IN DESIGNER GENES

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The ability of individuals to choose their children's genes has increased over time and may ultimately culminate in a world involving free market reprogenetic technologies. Reprogenetic technologies combine advances in reproductive biology and genetics to provide humans increased control over their children's genes. This Article offers economic perspectives that are helpful in understanding the possibly unexpected ethical, legal, and social issues at stake in using reprogenetic technologies for trait enhancement selection. The Appendix analyzes two competitive games that might arise in such a biotechnological society. Specifically, the Article focuses on herd behavior, caused by either a popularity contest or positional competition, in the choice of genetic traits. The analytical game-theoretic models in the Appendix can have several equilibrium outcomes in terms of individual reprogenetic technological choices and corresponding beliefs about such choices by others. This multiplicity of potential social outcomes suggests that a society can attain efficiency if the state or some private organization transforms individual parents' beliefs over the choices of other parents regarding their children's traits and, thus, coordinates parental reprogenetic decisions by selecting, as focal, certain beliefs over parents' reprogenetic decisions.

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> *Never forget who you are / Little star / Never forget how to dream / Butterfly / God gave a present to me / Made of flesh and bones / My life / My soul / You make my spirit whole / Never forget who you are / Little star / Shining brighter than all the stars in the sky / Never forget how to dream / Butterfly / Never forget where you come from / From love / You are a treasure to me / You are my star / You breathe / New life / Into my broken heart*[1]

INTRODUCTION

Reprogenetic technology combines advances in reproductive biology with genetics to provide individuals increased control over their children's genetic traits.[2] As an editorial from *The Economist* argued, "The proper goal is to allow people as much choice as possible about what they do. To this end, making genes instruments of such freedom, rather than limits upon it, is a great step forward. . . . [B]iology will be best when it is a matter of choice."[3] As with other forms of technology, however, a society can limit or even ban the use of designer genetics if there is reason to fear problems from its usage. Such techniques as human cloning, embryo selection, and genetic engineering raise many subtle and complex ethical, legal, and social issues ("ELSI"). This Article focuses on one of these issues, namely, the possible types of herd behavior that can occur in a free market world in which parents can delete or insert genes of their choice into their children.

One should notice that this Article is not entitled "designer traits," "designer babies," "designer children," or "designer adults."[4] These titles were not chosen because the majority of traits, and certainly those related to complex behavior, are polygenic[5] and multifactorial.[6] Genes are often described as "blueprints"[7] because they

1. MADONNA, *Little Star*, *on* RAY OF LIGHT (Warner Bros. Records 1998).

2. *See* LEE M. SILVER, REMAKING EDEN: HOW GENETIC ENGINEERING AND CLONING WILL TRANSFORM THE AMERICAN FAMILY 9 (1998) (defining reprogenetics).

3. *Changing Your Genes*, ECONOMIST, April 25, 1992 at 11, 12.

4. Michael D. Lemonick, *Designer Babies*, TIME, January 11, 1999, at 64-65 (discussing and reporting on surveys about designer genetics).

5. *See* MAXWELL J. MEHLMAN & JEFFREY R. BOTKIN, ACCESS TO THE GENOME: THE CHALLENGE TO EQUALITY 17-18 (1998) (defining polygenic traits as those for which more than a single gene is required for the trait's transmission).

6. *See id.* (defining multifactorial traits as those produced by both genetic and environmental factors).

7. Claudia Wallis, *Can Prayer, Faith and Spirituality Really Improve Your*

are said to contain "instructions for making various proteins."[8] The metaphor of a blueprint, however, implies a misleading level of precision and rigidity.[9] A better and more appropriate analogy is that genes are like cake recipes, which are simply a set of instructions that should, if followed properly, produce a cake or cake-like item.[10] Of course, as most people who have baked cakes or attended a cooking school will admit, there is much variation in the cakes created from an identical recipe. In the language of genetics, the instructions are the genotype, while the results are the phenotype. Genes do not determine phenotype.[11] Identical, or monozygotic, twins have the same genetic information, but develop quite differently when exposed to different environments.[12] Another useful analogy comes from playing cards, where players receive genetic hands, "but only in very rare cases does this automatically define a player as a winner or a loser. Rather, any outcome depends on how the cards are played, which in turn depends on how that play interacts with the playing of cards from other hands beyond the original player's control."[13]

The possibility of parents being able to alter their children's genetic make-up poses difficult and controversial ELSI and philosophical issues. For example, prenatal screening through amniocentesis may indicate the presence of a fetal genetic disease. A couple's subsequent decision to abort the fetus raises the issue of what constitutes a true deformity, as opposed to a mere difference.[14] Other

Physical Health? A Growing and Surprising Body of Scientific Evidence Says They Can, TIME, June 24, 1996, at 58, 61 (discussing the possibility that humans possess a genetic blueprint for believing in religion).

8. ERIC S. GRACE, BIOTECHNOLOGY UNZIPPED: PROMISES AND REALITIES 20 (1997).

9. *See* TIMOTHY H. GOLDSMITH, THE BIOLOGICAL ROOTS OF HUMAN NATURE: FORGING LINKS BETWEEN EVOLUTION AND BEHAVIOR 70-72 (1991) (describing the myth of biological determinism); Henk Jochemsen, *Reducing People to Genetics*, *in* GENETICS ETHICS: DO THE ENDS JUSTIFY THE GENES? 75, 77 (John F. Kilner et al. eds., 1997) (describing how the central dogma of molecular biology implies a genetically deterministic view of humans); Michael Ruse, *Knowledge in Human Genetics: Some Epistemological Questions*, *in* GENES AND HUMAN SELF-KNOWLEDGE 34, 38-42 (Robert F. Weir et al. eds., 1994) (discussing the dangers of methodological reductionism with the Human Genome Project).

10. *See* MARTIN BROOKES, GET A GRIP ON GENETICS 178-83 (1998) (providing the metaphor of cake recipes for genes).

11. *See* RICHARD LEWONTIN, HUMAN DIVERSITY 19 (1982) (discussing the common error that genes determine phenotypes).

12. *See* ROBERT PLOMIN ET AL., BEHAVIORAL GENETICS: A PRIMER 309-60 (2d ed. 1990) (describing twin studies and adoption designs); NANCY L. SEGAL, ENTWINED LIVES: TWINS AND WHAT THEY TELL US ABOUT HUMAN BEHAVIOR 20-35 (1999) (describing research on identical twins).

13. Charlie Davison, *Predictive Genetics: The Cultural Implications of Supplying Probable Futures*, *in* THE TROUBLED HELIX: SOCIAL AND PSYCHOLOGICAL IMPLICATIONS OF THE NEW GENETICS 317, 319 (Theresa Marteau & Martin Richards eds., 1996).

14. *See* Evelyn Fox Keller, *Nature, Nurture, and the Human Genome Proj-*

examples of reprogenetics include a dwarf couple who wants their child to be a dwarf[15] or a deaf couple who wants their child to be deaf.[16] In addition, there are constitutional and equity (in particular, affordability) issues raised by the prospect of a free market system of reprogenetics.[17] This Article does not focus on these interesting and important issues, nor does it deal with eliminating life-threatening or other so-called diseases. Instead, this Article focuses on genetic selection of what have been termed enhancements, such as height, weight, hair color, skin color, intellectual ability, or possibly pre-dispositions toward certain types of behavior. Although "parental eugenics," or, more descriptively, "homemade eugenics,"[18] are not currently feasible, they may be in the near future. One choice currently available to parents is the sex of their children. As Schelling noted, gender may serve as an effective proxy for other characteristics over which parents have preferences.[19]

It may seem that the ability to select the genetic traits of one's children has only the potential to make parents, and perhaps their children, better off because it enlarges the scope of choices available to parents. In standard single-person decision theory, the usual argument is that more choice, rather than less, renders an individual decision-maker better off. The reasoning is that if one of the additional choices is selected, then the individual has demonstrated, by making that choice, that she is better off than she would be without that option. If none of the additional alternatives are chosen, then the additional choices may simply be ignored.

The "revealed preference" argument, however, ignores the possibility that choice itself can create anxiety, concern, and regret about procedural or substantive issues related to choosing. The desire to avoid such feelings of anxiety or the responsibility of choice, as well as the costs of making fully-informed choices, provides alter-

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ect, *in* THE CODE OF CODES: SCIENTIFIC AND SOCIAL ISSUES IN THE HUMAN GENOME PROJECT 281, 298-99 (Daniel J. Kevles & Leroy Hood eds., 1992) (discussing the inherent ambiguity of what is considered "normal" and its cultural and socially constructed aspects).

15. *See* Faye Flam, *Designing the Family Tree a Road to Eugenics?*, BUFF. NEWS, June 25, 1995, at F7 (describing a dwarf couple's desire to genetically test their child for achondroplasia, the most common form of dwarfism).

16. *See, e.g.*, JOHN A. ROBERTSON, CHILDREN OF CHOICE: FREEDOM AND THE NEW REPRODUCTIVE TECHNOLOGIES 170-71 (1994) (discussing intentional diminishment); John A. Robertson, *Genetic Selection of Offspring Characteristics*, 76 B.U. L. REV. 421, 465-68 (1996) (discussing intentional diminishment from the perspective of parents' rights to procreative liberty).

17. *See generally* MEHLMAN & BOTKIN, *supra* note 5 (discussing various equity concerns raised by genetic technology).

18. Robert Wright, *Achilles' Helix*, THE NEW REPUBLIC, July 9 & 16, 1990, at 27 (describing "homemade eugenics" as "individual families deciding what kinds of kids they want to have").

19. THOMAS C. SCHELLING, MICROMOTIVES AND MACROBEHAVIOR 197 (1978) (discussing the possibility of choosing a child's sex).

native rationales for individuals to use rules, standards, delegates, randomizing devices, heuristics, or other second-order decision mechanisms.[20] In addition, the traditional argument that the alternatives not chosen may simply be ignored also ignores the nonconsequentialist value of having flexibility or options, even if those options are not used.[21] Finally, it is well known that having fewer choices available might be advantageous in strategic interaction, especially in bargaining.[22] This game-theoretic value of reduced options has applications in the designer genes context, as demonstrated in the Appendix.

There are two additional problems with individual choice that are unique to individual free market reprogenetics. The first is that certain individuals who know that some of their traits are the result of their parents' reprogenetic decisions may come to resent those choices. These individuals may come to wonder who they might have been, and care less for who they actually are, when those choices, such as a child's sex, are irreversible or reversible only at high cost. As in other contexts, the phrase "living up to one's potential" might prove a heavy burden. This is even problematic if the reprogenetic technology is only successful with a probability less than one.

Schelling discussed both possibilities and the clever example of how a couple's decision regarding a third child's sex may be viewed as their verdict on gender if that couple already had one child of each sex.[23] The more general potential source of inefficiency here is that parents make reprogenetic decisions to maximize their own utility, instead of the utility of their unborn children. In a sense, this is the well-known conflict of interest problem that arises in any principal-agent relationship. The fact that the principal is unborn when the agent makes the reprogenetic decision is akin to intergenerational conflicts that might arise in environmental contexts.

A new wrinkle is that parents influence their children's preferences both consciously and subconsciously. Of course, if parents make harmful choices with regard to their children, and a third

20. *See, e.g.*, CASS R. SUNSTEIN & EDNA ULLMAN-MARGALIT, SECOND-ORDER DECISIONS (University of Chicago Law School John M. Olin Law and Economics Working Paper No. 57, 2d Series 1998) (discussing various ways of making decisions).

21. *See* Kenneth J. Arrow, *A Note on Freedom and Flexibility*, *in* CHOICE, WELFARE, AND DEVELOPMENT: A FESTCHRIFT IN HONOR OF AMARTYA K. SEN 7-16 (Kaushik Basu et al. eds., 1995) (providing a formal model of the value of choices when preferences are flexible).

22. *See* AVINASH DIXIT & BARRY NALEBUFF, THINKING STRATEGICALLY: THE COMPETITIVE EDGE IN BUSINESS, POLITICS, AND EVERYDAY LIFE 152-55 (1991) (discussing historical examples of the strategic value of burning one's bridges).

23. SCHELLING, *supra* note 19, at 209-10 (discussing some consequences of having a choice of a baby's sex).

party can verify that harm, the state may intervene on the children's behalf. This policy, however, covers only harm to children once they are born. The wrinkle in the designer gene context is that such harm would not be apparent until the future, and is perhaps only probable. The California Supreme Court stated, in dictum, that if medical professionals warn parents that their child would be seriously ill, and the parents opt to proceed with the delivery, the child has a cause of action for wrongful life against the parents.[24] The California legislature then responded by enacting legislation stating that "[n]o cause of action arises against a parent of a child based upon the claim that the child should not have been conceived or, if conceived, should not have been allowed to have been born alive."[25] While wrongful life lawsuits raise interesting ELSI[26] and philosophical concerns,[27] this Article focuses on another concern with reprogenetic choice: namely, the possible herd behavior that can result as the aggregate outcome of uncoordinated individual choices.

Herd behavior in gene selection occurs when the utility that parents enjoy from a reprogenetic choice depends on the number of other parents who also make the same reprogenetic choice. This Article focuses on the demand for, as opposed to the supply of, reprogenetic technologies.[28] The supply of knowledge underlying reprogenetic technologies is ensured by the incentives of researchers to study and understand human genetics. The supply of reprogenetic technology is ensured by the profit motive. However, because it is impossible to put the gene back in the bottle, society can only learn how to best live with these new reprogenetic technologies.

The rest of this Article is organized as follows. Section I discusses possible sources of herd behavior for parental demand for reprogenetic technologies. Section II proposes a potential role for law

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24. *See* Curlender v. Bio-Science Lab., 165 Cal. Rptr. 477, 488 (1980).

25. CAL. CIV. CODE § 43.6(a) (Deering 1994).

26. *See, e.g.*, Alexander Morgan Capron, *Tort Liability and Genetic Counseling*, 79 COLUM. L. REV. 618, 661-66 (1979) (arguing that parents confronting a genetic risk should not face tort liability for deciding to conceive); Alexander Morgan Capron, *Informed Decisionmaking in Genetic Counseling: A Dissent to the "Wrongful Life" Debate*, 48 IND. L.J. 581, 603 (1973) (concluding that a child who suffers a genetic disease does not have a claim against the parents that decided to give birth despite the risks of the disease). *But see, e.g.*, Alexander Morgan Capron, *Which Ills to Bear?: Reevaluating the "Threat" of Modern Genetics*, 39 EMORY L.J. 665, 695 (1990) (stating that his position has to be inevitably reconsidered upon biotechnological progress and social pressures).

27. *See, e.g.*, Seana Valentine Shiffrin, *Wrongful Life, Procreative Responsibility, and the Significance of Harm*, 5 LEGAL THEORY 117, 148 (1999) (arguing for a more equivocal position regarding procreation).

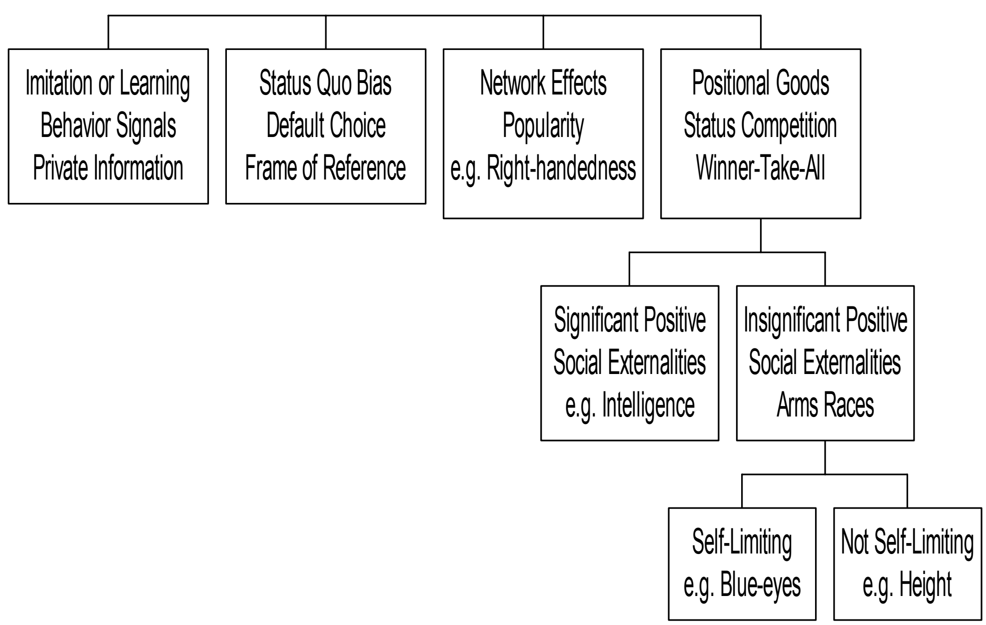
28. *See* Eric A. Posner & Richard A. Posner, *The Demand for Human Cloning*, *in* FACTS AND FANTASIES ABOUT HUMAN CLONING 233 (Martha C. Nussbaum & Cass R. Sunstein eds., 1998) (explaining that, if there were no demand or a slight demand for such procedures as human cloning, then society would have no reason to fear, and therefore regulate, the practice of reprogenetic technologies in order to prevent catastrophes).

and public policy in the effort to improve matters: namely, to provide a focal point for parents' concerns about whether other parents will choose to use reprogenetic technologies for particular traits, and to thereby help coordinate individuals' preferences regarding their children's genetic traits. Section III discusses other concerns that arise in a world of designer genes. The Appendix provides two formal game-theoretical models of herd behavior when parents' desires for particular genetic traits depend on the proportion of the population that also chooses those genetic traits for their children. Game theory permits formal analysis of such a "keeping up with the Joneses" phenomenon.

I. SOURCES OF HERD BEHAVIOR FROM INDIVIDUAL REPROGENETIC CHOICE

Herd behavior occurs when individual decision-makers imitate other decision-makers' choices. Such lemming-like behavior may or may not be a good thing, both from the viewpoint of individuals and society. A social welfare analysis of herding depends on the source of that behavior. There are at least five possible reasons for herding: learning from the behavior of others, the status quo bias, network effects, and positional goods or status competition with and without significant positive social externalities. These are depicted schematically in Figure 1. This Article will consider them in order.

Figure 1: Sources of Herd Behavior



First, decision-makers may have access to different information. If individuals are overly confident in their judgments,[29] then monitoring the actions of others could be desirable from both their own and society's perspectives.[30] Herding avoids duplicative information gathering or other decision-making costs. On the other hand, by simply mimicking the behavior of others, individuals and society may be worse off than if those people utilized their own private substantive information.[31] When behavior is considered a signal of private information, an availability cascade may result, whereby a belief is collectively formed in a self-reinforcing process, which gives that belief increased plausibility because of increased availability in public discourse.[32] Herding due to informational or availability cascades, however, is likely not yet a concern in the designer genes context.

The economist John Maynard Keynes, in stating that "[w]orldly wisdom teaches that it is better to fail conventionally than to succeed unconventionally,"[33] suggested that professional money managers may rationally practice investing with the herd to enhance reputations for investment abilities. Recent evidence suggests that younger fund managers follow the herd more than older fund managers because the younger ones are more likely than older ones to lose their jobs if their funds underperform the market.[34] Similar

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29. *See* Terrance Odean, *Volume, Volatility, Price, and Profit When All Traders Are Above Average*, 53 J. FIN. 1887, 1887 (1998) (demonstrating that overconfidence reduces the expected utility of those who are overconfident); Anne Kates Smith, *A Little Investment Horse Sense: Overconfidence, Not the Lack of Data, Is the Biggest Danger*, U.S. NEWS & WORLD REPORT, June 28, 1999, at 76 (reporting on empirical studies documenting overconfidence among horse race handicappers, discount-brokerage traders, and mutual fund investors).

30. *See* GARY BELSKY & THOMAS GILOVICH, WHY SMART PEOPLE MAKE BIG MONEY MISTAKES AND HOW TO CORRECT THEM: LESSONS FROM THE NEW SCIENCE OF BEHAVIORAL ECONOMICS 176 (1999) (discussing the possibility that overconfident people might overestimate their abilities to figure out what others think or know).

31. *See* Andrew Daughety & Jennifer Reinganum, *Stampede to Judgment: Persuasive Influence and Herding Behavior by Courts*, 1 AM. ECON. REV. (forthcoming 1999); *see also* Christopher Avery & Peter Zemsky, *Multidimensional Uncertainty and Herd Behavior in Financial Markets*, 88 AM. ECON. REV. 724, 728-30 (1998) (demonstrating the impossibility of informational cascades and herd behavior in financial markets when there is only a single dimension of risk). *But see* Eric Talley, *Precedential Cascades: A Critical Appraisal*, Olin Working Paper 99-6, U.S.C. Law School (1999), S. CAL. L. REV. (forthcoming Nov. 1999) (critically analyzing an informational cascade theory of legal precedent).

32. *See* Timur Kuran & Cass R. Sunstein, *Availability Cascades and Risk Regulation*, 51 STAN. L. REV. 683, 683 (1999) (defining "availability cascade").

33. JOHN MAYNARD KEYNES, THE GENERAL THEORY OF EMPLOYMENT INTEREST AND MONEY 158 (1936) (expressing skepticism over the capability and will of long-term investors to engage in contrarian investment strategies).

34. *See* Judith Chevalier & Glenn Ellison, *Career Concerns of Mutual Fund*

herd behavior and motivations could apply to decisions by banks to lend money to developing countries,[35] investments by corporate managers,[36] information gathering by short-term speculators,[37] and trading strategies by hedge funds and trading departments of investment banks.[38] In addition to such financial examples of herding, law students often herd in choosing legal courses, areas of practice, and summer or permanent associate positions at corporate firms. If later herd members differ in their tastes from earlier herd members, but are not aware of this difference, then later herd members are taking actions that maximize the preferences of earlier herd members instead of their own preferences. If preferences are malleable or culturally constructed, so that what is chosen becomes that which is desired, then it may be difficult for herd members or analysts to determine whether later herd members are better or worse off than they would have been in the absence of herding. The latter phenomenon can arise with certain traits, as modeled in the Appendix.

A second motivation for herding is the well-documented status-quo bias, which suggests that benchmarks matter for choices.[39] The status-quo bias is a bias toward default contract terms.[40] In times of changing social norms, the fact that preferences are often context-dependent means that what is considered the default option may effectively become mandatory. One way to avoid status-quo bias is to

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Managers, 114 QUART. J. ECON. 389, 409-16, 420, 430 (1999) (finding that, in a study of 453 fund managers, younger fund managers herd into more conventional portfolios and more popular sectors than older fund managers); Darren McDermott, *Young Managers Follow the Herd*, WALL ST. J., Aug. 2, 1999, at C1, C25 (reporting on studies that compared the investing practices of younger and older fund managers).

35. *See* SAMUEL GWYNNE, SELLING MONEY 58 (1986) (discussing the perverse incentives that a credit analyst faces in assessing country risk).

36. *See* David S. Scharfstein & Jeremy C. Stein, *Herd Behavior and Investment*, 80 AM. ECON. REV. 465, 465 (1990) (demonstrating that corporate managers can exhibit herd behavior in their investment decisions when they are concerned about their reputations in the labor market).

37. *See* Kenneth A. Froot et al., *Herd on the Street: Informational Inefficiencies in a Market with Short-Term Speculation*, 47 J. FIN. 1461, 1472 (1992) (demonstrating that short-term speculators may herd on the same particular sources of information that other informed traders know information completely unrelated to market fundamentals).

38. *See* Franklin R. Edwards, *Hedge Funds and the Collapse of Long-Term Capital Management*, 13 J. ECON. PERSP. 189, 206 (1999) (discussing the so-called "copycat" problem of many hedge funds and investment banks that have similar positions in order to make it difficult for all of them to liquidate their positions simultaneously).

39. *See* William Samuelson & Richard Zeckhauser, *Status Quo Bias in Decision Making*, 1 J. RISK & UNCERTAINTY 7, 8 (1988) (providing experiments that demonstrate the "status-quo bias").

40. *See* Russell Korobkin, *The Status Quo Bias and Contract Default Rules*, 83 CORNELL L. REV. 608, 608 (1998) (arguing that default rules in contract law may be sticky).

prevent actors from knowing the status quo, but such may not be possible in the context of designer genes.

A third rationale for herding is the presence of network externalities.[41] The concept of network externalities originated in the context of computer hardware, software, and telecommunications modes. In that context, a network externality occurs if the payoff or utility in choosing a particular type of computer hardware, software, or telecommunications mode is affected by the number of other users of the identical technology. For example, the utility of a particular type of computer hardware or software conceivably increases with the number of people who also choose that hardware or software because of increased consumer support, increased ability to exchange or share information with others, and increased resale to or help from other users. Similarly, the benefits of being part of the telephone system or the Internet increase with the number of people on that system. Network externalities have been applied to contract terms and corporate law.[42] Network externalities result in the potential for inefficiency that is, as with any type of externality, due to a conflict between individual rationality versus social optimality. Of course, as with many other cases of legal applications of economic ideas, the range of possible applications of network externalities to law may have been overstated.[43] In addition, in all of the above situations, there may be negative network externalities that result from congestion or delay if the herd size exceeds network capacity.

Examples of traits possibly exhibiting positive network externalities are right-handedness, due to the overwhelming availability of products for right-handed people, or a "language gene," which would facilitate the learning of multiple languages. Both situations are statically unproblematic if it is optimal for individuals to have those genes, but may be dynamically problematic due to lock-in effects from a large installed base should things change over time. The flip side of the above discussion is the fear that children with those genetic traits will be disfavored by society at large, which results in no children with those genetic traits. This potential all-or-nothing problem is related to the "tipping" phenomenon discussed in a famous book by Thomas Schelling.[44] Tipping refers to how aggre-

41. *See* HAL R. VARIAN, INTERMEDIATE MICROECONOMICS: A MODERN APPROACH 591-97 (4th ed. 1996); *see also* Michael L. Katz & Carl Shapiro, *Systems Competition and Network Effects*, 8 J. ECON. PERSP. 93, 97 (1994) (providing expositions of network externalities).

42. *See* Michael Klausner, *Corporations, Contracts, and Networks of Contracts*, 81 VA. L. REV. 757, 789-840 (1995) (providing applications network externalities to corporate contracts).

43. *See* Mark A. Lemley & David McGowan, *Legal Implications of Network Economic Effects*, 86 CA. L. REV. 479, 590 (1998) (assessing the appropriateness of applying network externalities to legal settings).

44. SCHELLING, *supra* note 19, at 204-05 (discussing tipping as a cultural consequence of selection).

gate patterns in social systems can sometimes easily tip from a non-extreme outcome toward an extreme outcome due to many uncoordinated individual decisions. An example of tipping is the possibility of a racially integrated neighborhood tipping into residential segregation if people prefer to live next to others of the same race.[45] Other examples of tipping include the dynamics of applause for an encore at the end of rock concerts and the sexual division of labor in childcare.[46]

Schelling raised the possibility of a massive unpopularity contest over such genetic traits as left-handedness or bald-headedness, in which "[a] normal characteristic could become a stigma through a myriad of uncoordinated individual choices."[47] Other such possible traits are skin color, eye color, and hair color. If parents can mask their children's race or ethnicity by reprogenetic technology as easily as individuals can alter their eye color by using colored contact lenses or their hair color by using hydrogen peroxide, a phenomenon mirroring that of "fake" versus "real" blondes could occur for ethnicity and race. Such unintended tipping is a sort of critical mass phenomenon, in which certain traits are valued precisely because a critical mass of sufficiently many others chooses those traits for their children.[48] Of course, a society can fail to achieve the required critical mass. An example of the failure of a critical mass to materialize was the number of consumers who chose to buy Beta format videotapes and videocassette recorders as opposed to VHS format videotapes and videocassette recorders. Also, the fact that everyone does not have the same hair or eye color, despite having the capabilities to alter either via dyes or contact lenses respectively, is evidence that expensive reprogenetic technologies may not reach a critical mass.

Sex is a trait that might stir a massive unpopularity contest. As Schelling and Robert H. Frank and Philip A. Cook pointed out, however, extreme gender imbalances are unstable for a monogamous society in the long run.[49] If men far outnumber women in a monogamous society, then most men will remain unmarried. Evidence of this phenomenon already exists in modern China.[50] Parents who

45. *See* THOMAS C. SCHELLING, THE STRATEGY OF CONFLICT 91 (1960) (applying tipping to residential segregation); Morton Grodzins, *Metropolitan Segregation*, 197 SCI. AM. 33, 34-40 (1957) (analyzing tipping points in the central parts of big cities).

46. *See* RHONA MAHONY, KIDDING OURSELVES: BREADWINNING, BABIES, AND BARGAINING POWER 55-56 (1995) (discussing examples of tipping).

47. *Id.* at 205.

48. *See* SCHELLING, *supra* note 19, at 101-02 (defining tipping in the context of neighborhood migration).

49. *Id.* at 200-02 (assessing "the relative merits of being in the majority or minority sex"); ROBERT H. FRANK & PHILIP A. COOK, THE WINNER-TAKE-ALL SOCIETY 185 (1995) (discussing the instability of demographic gender imbalance in a monogamous society).

50. *See* Philip Shenon, *A Chinese Bias Against Girls Creates Surplus of*

want grandchildren will opt for female children in order to increase their odds of becoming grandparents. Simultaneously, the social and economic status of women may rise, though such is a slow corrective process and is not necessarily permanent. In addition, during this interim adjustment process, the damage caused by the symbolic message that females are less valued in society than males could be permanent and very costly in psychological terms for women and men alike.

The final two motives behind herding involve positional goods or status competition. A drive to compete for higher status may be biologically ingrained.[51] A positional good is one more valued for its relative position along some particular scale than its absolute value.[52] Examples include income and wealth.[53] Survey data indicates that for physical attractiveness, intelligence, and years of education, "[p]osition matters more when choosing for one's child than when choosing for oneself."[54] An individual parent might have an incentive to invest at greater than efficient levels in genetic traits that are correlated with positional goods.[55]

A problem with positional goods is the inexorable logic that only the top ten percent of a distribution can be in the top ten percent of that distribution. Thus, along positional treadmills, the identity of those in the top ten percent of a distribution may change via competition, but neither the absolute number nor the relative proportion of those in the top ten percent can ever change. This problem of wasteful competition is analogous to raising prices in an inflationary spiral[56] and related to "winner-take-all markets," in which relative rather than absolute position is disproportionately rewarded.[57] Such markets occur when the winners of a competitive process in a

Bachelors, N.Y. TIMES, August 16, 1994, at A1, A8 (describing how the Chinese rule of one child per family and the customary Chinese preference for male heirs resulted in 205 million single Chinese males over the age of 15 in 1990).

51. *See* Nigel Nicholson, *How Hardwired is Human Behavior?*, 94 HARV. BUS. REV. 134, 143 (July-Aug. 1998) (discussing evidence from evolutionary psychology that concluded that competing for higher status is biologically ingrained, especially in males).

52. *See* FRED HIRSCH, SOCIAL LIMITS TO GROWTH 27-54 (1976) (arguing that positional goods limit economic growth).

53. *See* ROBERT H. FRANK, CHOOSING THE RIGHT POND 28-30 (1985) (arguing that concerns about relative standing explain many observed phenomena).

54. Sara J. Solnik & David Hemenway, *Is More Always Better?: A Survey on Positional Concerns*, 37 J. ECON. BEHAV. & ORG. 373, 373 (1998) (finding greater positional concerns for one's child than for oneself).

55. *See* LORI B. ANDREWS, THE CLONE AGE: ADVENTURES IN THE NEW WORLD OF REPRODUCTIVE TECHNOLOGY 148 (1999) (stating that while "[t]he gene for greed might help an individual get ahead on Wall Street . . . that might not be the best for the rest of us").

56. *See* SCHELLING, *supra* note 19, at 204 (noting that demographic consequences of choosing children's heights is analogous to inflation).

57. FRANK & COOK, *supra* note 49, at 2-3 (providing a definition for and examples of "winner-take-all markets").

market receive all or most of the economic value of that market.[58] Examples include those for superstar athletes, movie stars, supermodels, rock stars, best-selling novelists, famous directors, and certain investment bankers and lawyers. A winner-take-all society is one in which the mentality of such markets permeates all or most social interaction. Such a view of society is related to a one-size-fits-all view of government and other institutions. It is the antithesis of a society in which everyone has a chance to win together.[59]

Status competition with significant positive social externalities may offset the wasteful competition of positional goods. An example would be if the absolute increases in intelligence that result from parents choosing those genes correlates with higher intelligence and generates benefits for society as a whole in terms of increased creativity and productivity. Even status competition without any significant positive social externalities may not be problematic if it is for some reason self-limiting. Thus, parental desires for blue-eye genes may reverse once a critical mass of blue-eyed children appears.

For some genetic traits, parental tastes may be nonlinear functions of how many other parents choose the same or similar traits. As is the case with baby names, parents may want genes for their children that are neither too different nor too popular. Status competition without any significant positive social externalities that is not self-limiting, however, may result in an unending race, since there is no upper boundary for values of the genetic trait. An example of such a genetic trait might be body size for men. Frank and Cook, as well as Schelling, raise the possibility of a prisoner's dilemma regarding body size.[60]

Body size has features of a positional good. Individual males may have a relative advantage from being taller than average[61] and

58. "Winner-take-all markets" may more accurately be described as "those-near-the-top-get-a-disproportionate-share markets." *Id.* at 3.

59. *See* LANI GUINIER ET AL., BECOMING GENTLEMEN: WOMEN, LAW SCHOOL, AND INSTITUTIONAL CHANGE 1 (1997) (criticizing a one-size-fits-all view of society and resulting policies).

60. FRANK & COOK, *supra* note 49, at 185-86 (discussing the race for larger children); SCHELLING, *supra* 19, at 204, 209 (discussing the prisoner's dilemma regarding children's body sizes). The prisoner's dilemma is perhaps the most famous game in all of game theory and is the subject of much literature. *See, e.g.*, WILLIAM POUNDSTONE, PRISONER'S DILEMMA (1992) (providing an exposition on the prisoner's dilemma).

61. *See* FRANK & COOK, *supra* note 49, at 185 (citing two studies that report that height confers an individual advantage in men's earnings and Presidential elections). The two studies discussed by FRANK & COOK are Liz Doup, *Tall or Short, Life is a Game of Inches*, CHI. TRIB., Sept. 7, 1992, at C1 (reporting on a University of Pittsburgh study of salaries for their graduates and a study of recruiters' preference 72% of the time for the taller of equally qualified male candidates) and Maureen Dowd, *Where They Stand*, N.Y. TIMES, June 21, 1992, § 9, at 1 (reporting that the taller candidate won in 18 of the last 22 U.S. Presidential elections).

larger than average.[62] The vast market for genetically engineered human growth hormone ("HGH") in the United States, where very few children suffer from dwarfism, testifies to the demand for taller children by parents and children alike.[63] Society as a whole, however, is not better off, and may actually be worse off, when average body size increases because it leads to greater food consumption, taller and wider doorways, and increased susceptibility to orthopedic problems. There is evidence that some non-human animals have body sizes that are too large.[64]

Male body size has the potential for causing a positional (possibly, quite literal) arms race.[65] The phrase "arms race" became popular during the Cold War between the United States and the former Soviet Union in connection with the production and stockpiling of Inter-Continental Ballistic Missiles. The phrase "positional arms race" describes a situation where decision-makers compete to secure a higher position relative to others. The race between the United States and the former Soviet Union to land men on the moon and bring them back safely was a positional arms race. Another familiar example occurs when individuals try to "keep up with the Joneses" in terms of income or (more easily observable, conspicuous) consumption.[66] Steroid use among athletes may result from a positional arms race to win medals. Finally, among many Chinese parents, there is a positional arms race over their children's grades in elementary school.[67]

Another trait that parents may desire for their children is physical attractiveness. At least three reasons exist for such a preference: intrinsic aesthetics, the belief that physical attractiveness is an advantage in finding a spouse, and the belief that physical at-

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62. *See* FRANK & COOK, *supra* note 49, at 185 (mentioning the advantage of being larger in athletic contests). *But see* Doup, *supra* note 61, at A1 (discussing studies that indicate rates of cancer may increase with height and longevity may decrease with height).

63. *See* Sally Lehrman, *The Fountain of Youth?*, HARV. HEALTH LETTER, June 1992, at 1; Joannie M. Schrof, *Pumped Up*, U.S. NEWS & WORLD REPORT, June 1, 1992, at 55, 62 (reporting on a survey of 10th grade suburban Chicago boys that found five percent claimed to have used HGH despite its $1500 price for a two-week supply).

64. This paleontological finding is known as Cope's law. *See* Richard Kerr, *Growth, Death, and Climate Featured in Salt Lake City*, 278 SCIENCE 1017 (1997).

65. *See* FRANK & COOK, *supra* note 49, at 127-31 (describing positional arms races).

66. *See* THORSTEIN VEBLEN, THE THEORY OF THE LEISURE CLASS 75 (1899) (discussing how conspicuous consumption of valuable goods can be a signal of wealth).

67. *See* THE JOY LUCK CLUB (Buena Vista Home Video 1993). In this context, such parents often believe the production function for higher grades by their children to be stricter discipline and/or more severe punishments for lower grades.

tractiveness is an advantage in the job market.[68] Of course, what constitutes beauty is culturally and historically contingent, but there is strong evidence that "within a culture at a given point in time there is tremendous agreement on standards of beauty, and these standards change quite slowly."[69] In addition, there is evidence that "[w]e're unconsciously attracted to those things that indicate good genes."[70] For example, "humans consider symmetrical faces more attractive than uneven ones."[71] Thus, facial symmetry may be a factor in selecting from among job candidates, potential mates, and even candidates for President of the United States.[72] In the context of physical attractiveness, the concern is not an unbounded race to greater levels of beauty, but rather a race toward uniformity in physical appearance. Of course, there is the possibility of multiple ideals instead of a unique physical appearance. It would be interesting to learn whether plastic surgeons received the same kinds of requests from their patients or if the patients varied in their choices.

The common feature of genetic traits desired either for their expected popularity or their positional value is that their desirability depends positively or negatively on the fraction of the population with that genetic trait. The Appendix of this Article explicitly constructs two analytical game-theoretic models of herd behavior for the reprogenetic selection of specific genes. The next Section of this Article discusses the potential roles that the law and public policy may play as reprogenetic technologies continue to advance.

II. ROLES FOR LAW AND PUBLIC POLICY

The prospect that individually-chosen reprogenetics can lead to herd behavior is formally demonstrated in the Appendix. Two game-theoretic models demonstrate how complete tipping is not the only possible equilibrium outcome that occurs with genetic traits valued for their popularity or positional nature. The development of a reprogenetic technology can, but does not have to, move society

68. *See* Daniel S. Hamermesh & Jeff E. Biddle, *Beauty and the Labor Market*, 84 AM. ECON. REV. 1174, 1180-85 (1994) (finding that, for both sexes in all occupations, with the wage effects for men at least as large as the wage effects for women, plainness entails a 5-10% wage penalty compared to average-looking people, while physical attractiveness commands a 5% wage premium compared to average-looking people, holding all other things constant).

69. *Id.* at 1175.

70. John Harwood, *Could a Candidate in a Presidential Race Win It by a Nose*?, WALL ST. J., June 24, 1999, at A1.

71. *Id.*; ROGER GOSDEN, DESIGNING BABIES: THE BRAVE NEW WORLD OF REPRODUCTIVE TECHNOLOGY 91 (1999) (reporting that, among humans, women find symmetric males to be more attractive).

72. *See* Harwood, *supra* note 70, at A6 (discussing the importance of emotional reactions to facial symmetry in voter preferences for Presidential candidates).

from a status quo equilibrium where the reprogenetic technology is not used at all (because it does not exist yet) to an ex-post equilibrium where everyone uses it. Legal prohibition may be ineffective at preventing such complete tipping because of the rapid and global nature of reprogenetic technological progress and information dissemination, which lowers the cost of using reprogenetic technologies and forces any regulatory agent to chase a moving target. Game theory, however, demonstrates that there may be a third intermediate and possibly more realistic equilibrium in which only partial tipping occurs.

Consumer demand for employing reprogenetic technologies may exhibit herd behavior, thus making it difficult for individual parents to resist using them. This Section suggests that one solution is to change people's beliefs about how many others will use reprogenetic technology. In particular, law and public policy have the potential to prevent complete tipping, resulting in a society with no tipping, or more realistically, partial or incomplete tipping to the adoption of a particular reprogenetic technology. For example, as for those traits desired for their positional nature, government-subsidized market or state provision of the reprogenetic technology reduces the desirability of such traits by increasing the proportion of the population expected to possess them. Inexpensive and equal access to reprogenetic technologies also means an equitable allocation of the fruits thereof.

Another possibility for affecting people's individual reprogenetic technology choices is to alter their behavior, not indirectly through their beliefs about others' behavior, but by changing the underlying preferences themselves. In the formal notation of the model, law and public policy may be designed to either change probability beliefs (Π) and, therefore, indirectly belief-dependent expected utilities [$EU(\Pi)$]; or change directly the functional form of the utility function (U) so that people's preferences over genetic traits do not exhibit herd behavior. Criminal law, for example, may have such a direct preference-shaping role, in addition to its role in changing the costs of criminal behavior in terms of increasing expected fines or expected length of imprisonment.[73]

A final possible source of friction along the slippery slope of reprogenetic technology adoption is that parents may desire their children to look and act like the parents themselves. Even were it the case that taller people do better in life, short parents may not want a tall child or non-blond parents may not want a blond child. In other words, parents may want their children to look like them, not only because adoption or genetic engineering would otherwise be obvious, but also for narcissistic reasons. The question of what par-

73. *See, e.g.*, Kenneth G. Dau-Schmidt, *An Economic Analysis of the Criminal Law as a Preference-Shaping Policy*, 1990 DUKE L.J. 1 (suggesting the role of criminal law in changing preferences).

ents prefer for their children becomes even more problematic in the realm of non-physical traits, such as intelligence. The prospect of children who are, say, significantly smarter than their own parents, and thus quite unlike them, may be quite discomforting for some parents. The ambivalence that some immigrants to the United States felt about children who spoke "better," unaccented English might be, in part, a reflection of this kind of concern.

The formal models in the Appendix suggest a number of possible roles for law and public policy in helping a society to solve the coordination problem by selecting a set of beliefs about what others will do as focal, thus changing behavior. For example, the law could prohibit the use of reprogenetic technology. If law enforcement is legitimate, it will become self-enforcing. This is analogous to the mere insurance of individual bank deposits (less than $100,000) by the Federal Deposit Insurance Corporation, which prevents liquidity and fear-induced bank runs.[74] Of course, a policy implication is that punishment of high-profile violators must be public and swift. If law enforcement cannot curtail illegal use of undetectable reprogenetic technology, both within U.S. boundaries and outside, then a ban will likely be ineffective.

Instead of an absolute prohibition, perhaps a state could tax consumer spending on reprogenetic technologies and allocate the proceeds to a fund that helps provide the poor with access to reprogenetic technologies.[75] This policy would improve concerns over the distribution of access to reprogenetic technologies. It would also be consistent with a policy for taxing luxury items. The exclusion of reprogenetic technologies from health insurance coverage would be similar to a tax on reprogenetic technologies.

Another alternative to legal prohibition would be a public policy of an "educational" campaign aimed at changing parents' beliefs about what other parents will do and, thus, parents' belief-dependent expected utilities. For example, attaching shame to the use of a reprogenetic technology would be one possibility. This is easier to do if a particular technology involves potentially harmful side effects. Frank and Cook provide a hypothetical example of a reprogenetic technology that permits a child with 99% probability to score 15% higher on standardized tests, but also causes severe emotional disability with 1% probability.[76] Of course, the shame a parent suffers might itself depend on beliefs about what proportion of

74. *See* XAVIER FREIXAS & JEAN-CHARLES ROCHET, MICROECONOMICS OF BANKING 191-94 (1997) (providing a model of liquidity insurance for banking deposits).

75. *See* ROBERT H. FRANK, LUXURY FEVER: WHY MONEY FAILS TO SATISFY IN AN ERA OF EXCESS 203-06 (1999) (advocating a tax on luxury consumption in general).

76. FRANK & COOK, *supra* note 49, at 186 (discussing the hypothetical of risky genetic enhancement).

society will employ this reprogenetic technology.[77] Morality, ethics, popular culture, and religious beliefs also influence parents' expectations over what other parents will decide about reprogenetic technologies.[78]

Popular culture is replete with examples of the dangers of biotechnological innovation. In the film *Star Trek: Insurrection*, certain officers conspire to implement a technological fountain of youth despite its destruction of a planet inhabited by the *Ba'ku*, a race of six hundred.[79] The *Ba'ku* appear to be a primitive culture, but in reality they have chosen to forsake so-called advanced technology in favor of a much simpler and idyllic existence.[80] The potentially dark side of science and technology was also captured aptly in Mary Shelley's novel, *Frankenstein*.[81] More recently, the novel and blockbuster movie, *Jurassic Park*, and its sequel, *The Lost World: Jurassic Park*, showed the human folly of genetically recreating dinosaurs from deoxyribonucleic acid ("DNA") preserved within a fossilized mosquito.[82] Another science-fiction film, *Blade Runner*, and the novel upon which it was based, *Do Androids Dream of Electric Sheep?*, painted a portrait of a surreal, futuristic Los Angeles where genetically-created androids, known as replicants, were difficult to distinguish from their human creators.[83] In yet another science-fiction film, *Species*, disaster occurred when genetic engineers combined human and extraterrestrial DNA, while in the sequel, *Species II*, genetic engineers cloned the result of that combination to combat an extraterrestrial combination of human DNA with extraterrestrial DNA.[84] Most recently, the hit film *The Matrix* portrayed a future Earth where machines with artificial intelligence "grow" humans for their bio-energy.[85]

In the 1930s, the downside of biotechnology was vividly depicted by the state-controlled fetal hatcheries in Aldous Huxley's novel

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77. For formal analytical models of such belief-dependent guilt, see Peter H. Huang & Ho-Mou Wu, *More Order Without More Law: A Theory of Social Norms and Organizational Cultures*, 10 J.L. ECON. & ORG. 390, 395 (1994).

78. *See* Daniel J. Kevles & Leroy Hood, *Reflections*, *in* THE CODE OF CODES, *supra* note 14, at 319-20 (discussing strong religious and philosophical objections to reprogenetics).

79. STAR TREK: INSURRECTION (Paramount Pictures 1998).

80. *See id.*

81. MARY SHELLEY, FRANKENSTEIN; OR, THE MODERN PROMETHEUS (Univ. of Cal. Press, 1984); JON TURNEY, FRANKENSTEIN'S FOOTSTEPS: SCIENCE, GENETICS AND POPULAR CULTURE 3 (1998) (describing Frankenstein as "the governing myth of modern biology").

82. MICHAEL CRICHTON, JURASSIC PARK (1990); JURASSIC PARK (Universal Pictures 1993); THE LOST WORLD: JURASSIC PARK (Universal Pictures 1997).

83. BLADE RUNNER (Facets Video 1982); PHILIP K. DICK, DO ANDROIDS DREAM OF ELECTRIC SHEEP? (1968).

84. SPECIES (MGM 1995); SPECIES II (MGM/United Artists 1998).

85. THE MATRIX (Warner Brothers 1999).

Brave New World.[86] In the novel, humans were assigned predetermined roles in a society devoid of marriage or parenthood and were convinced via the assistance of mood-altering drugs and state propaganda to be content with their genetic lot in life.[87] Although the phrase "brave new world" is often used in reference to a horrific, soulless, and worldwide state-run society, individuals in a democratic, free-market society may utilize reprogenetics easily, and are perhaps more likely to do so than those in a centralized global state.[88] In the science-fiction movie *Gattaca*, the lead character is a non-genetically-enhanced human who masquerades as a genetically-enhanced individual in order to qualify as an astronaut, rather than a janitor.[89] In the film, society is divided between humans conceived in the "old-fashioned" manner and the genetically-engineered elite.[90] Though *Gattaca* takes place in the distant future, author Jeremy Rifkin warns that, within twenty-five years, "[m]eritocracy could give way to genotocracy, with individuals, ethnic groups, and races increasingly categorized and stereotyped by genotypes, making way for the emergence of an informal biological caste system in countries around the world."[91]

III. OTHER CONCERNS WITH DESIGNER GENES

Even if parents' tastes for their children's genetic traits do not exhibit herd behavior, there are other concerns involving the prospect of designer genes. Among these is the notion of virtual children, who are the result of parents' opting to pass to their offspring parts of their own genetic profiles.[92] While such a concept may seem impossibly far-fetched, a technological form of prenatal screening of an embryo for genetic defects already exists.[93] Preimplantation genetic diagnosis ("PGD"), or embryo biopsy, is only available for em-

86. ALDOUS HUXLEY, BRAVE NEW WORLD (1932) (portraying a future where a world government utilizes fetal hatcheries to breed children into predetermined intellectual classes, ranging from alphas (those at the top) to epsilons (those at the bottom)).

87. Thanks to Amanda Spitzer for noting the importance of pharmaceutically-induced and state-indoctrinated bliss in BRAVE NEW WORLD.

88. *See* BRYAN APPLEYARD, BRAVE NEW WORLDS: STAYING HUMAN IN THE GENETIC FUTURE 85 (1998) (describing the pressures on governments and parents to use reprogenetics).

89. GATTACA (Columbia Pictures 1997). The four letters that are used in the word "gattaca" are the four DNA bases—adenine, cytosine, guanine, and thymine. *See* BROOKES, *supra* note 10, at 12 (describing the DNA bases).

90. *See* GATTACA (Columbia Pictures 1997).

91. JEREMY RIFKIN, THE BIOTECH CENTURY: HARNESSING THE GENE AND REMAKING THE WORLD 3 (1998).

92. *See* SILVER, *supra* note 2, at 233-65 (discussing the idea of virtual children).

93. *See id.* at 237; *see also* BROOKES, *supra* note 10, at 120-21 (describing PGD and IVF technologies).

bryos produced by a process known as *in vitro* fertilization ("IVF").[94] IVF allows infertile couples to conceive "test-tube babies" and makes it possible to read and change an embryo's genetic information.[95] The initial negative reaction toward IVF has been replaced by steady acceptance, as thousands of babies are conceived through IVF yearly.[96] While PGD is currently useful to only a small number of couples with a history of a serious genetic disease and medical or ethical objections to abortion, improved PGD technology may make parental embryo selection a reality for all who desire and can afford it very soon.[97]

If it were possible for parents to utilize PGD to screen embryos, there are several moral and social concerns that would also be true of designer genes and that have already been ably considered by Lee Silver.[98] Moral concerns include a natural order argument (why, though, is the current random process of gene transmission the natural one?) or the worry that choosing one virtual child over another would be immoral (virtual children, however, are not actual children). Social concerns include the impact of embryo selection on the gene pool (eliminating the 5000 or so known genetic diseases, including sickle cell anemia or cystic fibrosis, risks limiting future evolutionary options)[99] or the potential for discrimination (but, how different are genetic inoculations against disability from polio vaccine inoculations?). A world of designer genes offers couples a menu of choices, not just from among their particular genes, but from any genes imaginable, human or not.[100]

There are several new concerns with a world of designer genes that did not arise in the context of virtual children, where parents choose from among the embryos that they have conceived based on the genetic profiles of those embryos. A free market society where parents can buy any package of genetic traits for their children runs the risk of commodification of children, and with it a risk of universal commodification.[101] Although universal commodification is an empirical possibility, a formal game-theoretic model demonstrated

94. *See* SILVER, *supra* note 2, at 237.

95. *See id.* at 87 (describing the reprogenetic possibilities IVF allows).

96. *See id.* at 80, 88 (documenting transformation of public's attitudes towards IVF).

97. *See id.* at 243-47 (describing potential solutions to the technical problems limiting PGD).

98. *See id.* at 255-65 (raising and responding to moral and other concerns raised by widespread PGD).

99. "For example, the sickle-cell recessive trait protects against malaria. The cystic fibrosis recessive gene may play a role in protecting against cholera." RIFKIN, *supra* note 91, at 146.

100. *See* SILVER, *supra* note 2, at 278-80 (discussing the possibilities of human enhancements).

101. *See* MARGARET JANE RADIN, CONTESTED COMMODITIES: THE TROUBLE WITH TRADE IN SEX, CHILDREN, BODY PARTS, AND OTHER THINGS 154-63 (1996) (discussing the perils of commodification).

that it is not inexorable.[102] The prospect of made-to-order "boutique babies" also raises the specter of children being viewed (even more so than today) as the private property of their parents.

Throughout American history and law, owners have had much discretion as to how they may treat their private property. In particular, owners are free to neglect, or even dispose of, their property in any manner they see fit unless doing so creates a nuisance or violates the public interest. Viewing children as their parents' property is naturally in opposition to individual's owning their own bodies as part of the constitutive personhood.[103] Finally, designer children, even more so than virtual children, stir the controversial and thorny question of what constitutes a genetic abnormality, defect, error, or risk.

Once life-threatening diseases are "cured," why not genetically eliminate such merely inconvenient diseases as diabetes, high blood pressure, myopia, obesity, asthma, or predisposition to breast cancer? Why stop with disease? Why not buy genetic predispositions for certain types of parentally-desired behavior? In other words, why not allow for all the genetic enhancements discussed earlier in this Article? One reason is that such transactions can have a huge negative impact on the self-worth of those people whose parents were unable to afford or unwilling to buy into society's prototype of the ideal human. We have already seen a similar phenomenon in the development of cosmetic surgery as a high-growth luxury consumption item.[104] As with face lifts and nose jobs, however, neither banning reprogenetic technologies nor imploring a parent to single-handedly refrain from the services of a genetic enhancement clinic is likely to succeed because supply does not create its own demand.

In other words, once a technology develops, it only becomes widely utilized if a sufficient number of consumers are willing to pay enough for its "products." As with the failed war on illegal drugs, there are two sides of the marketplace at which government can direct public resources and policy: demand and supply. The supply of reprogenetic technologies is determined by commercial feasibility. The demand for reprogenetic technologies is hopefully more malleable than some think. After all, tastes are acquired and can be refined over time with experience. Yet, there is recent evidence that the neurotransmitter serotonin and the male sex hormone testosterone are biochemical markers of human concerns about relative position.[105]

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102. *See* Peter H. Huang, *Dangers of Monetary Commensurability: A Psychological Game Model of Contagion*, 146 U. PA. L. REV. 1701, 1701-22 (1998) (demonstrating the logical possibility of incomplete commodification).

103. *See* MARGARET JANE RADIN, REINTERPRETING PROPERTY 35 (1993) (discussing personhood).

104. *See* FRANK, *supra* note 75, at 25-27 (discussing facts about cosmetic surgery).

105. *See id.* at 140-42; *see also* Douglas Madsen, *Serotonin and Social Rank*

There are certain dangers of designer genes that not only apply to virtual children, but also to non-genetic parenting decisions. Glenn McGee introduced a catalogue of five such decision-making pitfalls that apply generally to all parental choices, genetic or not: calculativeness, hasty judgment, shortsightedness, overbearance, and pessimism.[106] The first is a tendency to overstress the importance of controlling, planning and systematic decision-making in parenting. Parents who fall into this trap may select genetic over conventional and more labor- and time-intensive parenting, since the former offers the illusion of determinism. Of course, genetics and the environment combine to influence the outcome of parenting. There remains the possibility that, by using designer genes, couples undervalue the caretaking and environmental aspects of parental responsibility and end up diminishing the emotional bonds between themselves and their offspring. Parents may substitute genetic enhancement—or for that matter, private schooling, music lessons, and summer camps—for time, attention, and personalized mindfulness.

The remaining parenting dangers result from the simple, but unavoidable, notion of uncertainty. Parents who rush to design a perfect child may come to find "Barbie" or "Ken" the victim of unexpected natural disasters, environmental conditions, or peer envy in an imperfect world. A Chinese saying reminds us that "the flower that blooms in adversity is the most rare and beautiful of all."[107] In other words, a flower that has experienced adverse natural conditions has adapted to its environment and will more likely survive than the flower that has never been subjected to adverse weather. A classic *Star Trek* episode told of a perfect android who died from an inability to handle strong, new, and conflicting emotions.[108] Similarly myopic selection of designer genes can result in outdated babies. Being an overbearing parent is related to viewing one's children as property to be forged into a particular mold. As McGee stressed, "The key is to avoid extreme measures through biological *or any other means*, and to temper decisions before birth with the recognition that every child has a right to make some decisions about her own identity."[109] Part of being an overbearing parent is making one's children feel guilty for not achieving their genetic potential. Finally, while reprogenetic technologies offer parents new choices, such choices often are nearly the moral equivalent of many

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Among Human Males, *in* THE NEUROTRANSMITTER REVOLUTION: SEROTONIN, SOCIAL BEHAVIOR, AND THE LAW 146, 151 (Roger T. Masters & Michael McGuire eds., 1994) (reporting on laboratory studies finding a link in young adult males between social rank and whole-blood serotonin).

106. GLENN MCGEE, THE PERFECT BABY: A PRAGMATIC APPROACH TO GENETICS 123-33 (1997) (discussing sins that parents should avoid).

107. MULAN (Disney 1998).

108. *Requiem for Methuselah* (Paramount 1969).

109. MCGEE, *supra* note 106, at 127.

existing parental choices. Such moral equivalence means that reprogenetic decisions may not lead us down the proverbial slippery slope into biological tragedy because of the friction provided by social norms and cultural influences that already operate in all spheres of human decision-making.

The above decision traps urge parents and society to proceed cautiously and gradually in the utilization of reprogenetic technologies. An example is utilizing somatic therapy instead of germ line therapy.[110] In the former, only somatic cells, the body's non-sex cells, undergo genetic changes.[111] Thus, only the individual undergoing the somatic therapy is altered. In the latter, the sex cells undergo genetic changes. Hence, not only is the individual undergoing the germ line therapy genetically altered, but future generations are altered as well. In this manner, germ line therapy can affect how all of humanity evolves as a species, while somatic therapy is a more cautious approach to genetic intervention.[112]

The above conclusion to proceed carefully and slowly in decision-making is not unique to designer genes, but applies to any situation involving a large degree of uncertainty; for example, it applies not only to human reprogenetic technologies, but also to genetically engineered food.[113] In the language of modern financial theory, there is much to be said for preserving option values until a decision-maker acquires more information.[114] In fact, the analogy of genetic engineering to financial engineering suggests five perhaps unexpected insights.

First, the returns to any particular security may be correlated, positively or negatively, with the returns to some other securities.[115] The analogue in a genetic setting is that a particular genetic trait might be associated with the presence or absence of some other genetic traits. For example, there is "the demonstrated association between manic depression (also known as bipolar affective disorder)

110. *See* GRACE, *supra* note 8, at 215-17; *see also* MICHAEL J. REISS & ROGER STRAUGHAN, IMPROVING NATURE? THE SCIENCE AND ETHICS OF GENETIC ENGINEERING 202-23 (1996) (providing examples of the debate over gene therapy and the distinctions between somatic and germ line versions of gene therapy).

111. Sex cells, such as those present in the male testes, female ovaries, or embryos, are more formally known as gametes. *See, e.g.*, BROOKES, *supra* note 10, at 21 (defining sex cells).

112. *See* RIFKIN, *supra* note 91, at 27 (discussing the differences between gene therapies conducted on somatic versus germ line cells).

113. *See* BROOKES, *supra* note 10, at 128-33 (discussing concerns about genetically engineered food).

114. *See* Martha Amram & Nalin Kulatilaka, *Disciplined Decisions: Aligning Strategy with the Financial Markets*, 95 HARV. BUS. REV. 95-100 (Jan.-Feb. 1999) (discussing the value of real options).

115. *See* DAVID G. LUENBERGER, INVESTMENT SCIENCE 144-45 (1998) (discussing covariance and correlation).

and creative genius."[116] The film *Star Trek II: The Wrath of Khan* suggested the possibility that heightened intelligence and physical strength may coincide with heightened aspirations and ambitions.[117] Second, due to the first observation, modern portfolio theory stresses the importance of a diversified investment portfolio.[118] The genetic setting analogue is that it is important for parents to choose a diversified set of designer genes for their child in order for that child to be able to thrive under unforeseeable circumstances. Third, because of technological complexities, financial engineering might be misunderstood and misused.[119] The analogue in a genetic setting is that, because of technological complexities, designer genes might be misunderstood and misused. Fourth, because of the third point, United States federal securities law is based on a philosophy of mandatory disclosure rules and anti-fraud regulations.[120] The analogue in a genetic setting is to base federal regulation of reprogenetic technologies on a similar philosophy of informed consent after consultation with genetic counselors and other health professionals. Fifth, due to increased globalization and computer or information technological advances, financial engineering makes it possible for investors to circumvent any particular country's jurisdiction by international arbitrage and to get around laws that only govern certain types of securities by regulatory arbitrage.[121] The analogue in a genetic setting is that any individual sovereign's attempted regulation of designer genes drives reprogenetic technologies offshore and that narrowly defined regulations about certain types of reprogenetic technologies are doomed to fail because of the ability to achieve identical reprogenetic outcomes utilizing substitute reprogenetic technologies.

CONCLUSION

This Article considers a future society in which parents have increased abilities to choose their children's genetic composition. In such a free market society, unbridled consumer sovereignty may

116. SILVER, *supra* note 2, at 259.

117. STAR TREK II: THE WRATH OF KHAN (Paramount 1982).

118. *See* LUENBERGER, *supra* note 115, at 151-55 (discussing the value of diversification).

119. *See generally* FRANK PARTNOY, FIASCO: THE INSIDE STORY OF A WALL STREET TRADER (1999) (detailing examples of alleged customer ignorance and client abuse regarding financial engineering).

120. *See* Joseph A. Grundfest, *Securities Regulation*, *in* 3 THE NEW PALGRAVE DICTIONARY OF ECONOMICS AND THE LAW 410, 412-13 (Peter Newman ed., 1998) (discussing mandatory disclosure and antifraud prohibitions).

121. *See* MICHAEL S. KNOLL, PUT-CALL PARITY AND THE DEVELOPMENT OF THE MODERN MORTGAGE (U.S.C. Law Center Working Paper No. 94-12, 1994); Frank Partnoy, *Financial Derivatives and the Costs of Regulatory Arbitrage*, 22 J. CORP. L. 211, 227-54 (1997) (discussing regulatory arbitrage via financial engineering).

cause herd behavior and social pressures to keep up with individual parents. Herd behavior can lead to less than efficient levels of investment by parents in certain genetic traits of their children and possibly even to a society without certain unpopular genetic traits. This lack of diversity is the sort of all-or-none outcome that occurs in tipping models.[122] Herd behavior can also lead to greater than efficient levels of investment in other genetic traits that have positional value. This type of over-investment is the sort of inefficiency that occurs in signaling models.[123]

Even if parents' tastes for their children's genes do not exhibit herd behavior, other concerns arise in the advent of designer genes. Some of these occur with the notion of virtual children who are the product of parental selection among embryos. For example, there are moral and naturalness anxieties. In addition, expanding the choice set for parents from "their" genes to "any" genes introduces a host of novel possibilities, including that of humans possessing scales or gills.[124] Designer genes, however, also entail several new conundrums. These include Radin's fear of commodifying children, and, thus, another domino toward universal commodification, as well as her discussions of personhood.[125] In addition, the prospect of designer children renews the solicitude of greater intolerance of genetic variation.

Of course, there are potential risks with designer genes that are true of all parenting decisions: calculativeness, hasty judgment, shortsightedness, overbearance, and pessimism. These decision traps stem from uncertainty regarding the consequence of choosing designer genes, and from parental choices in general. In fact, the analogy of genetic engineering to financial engineering suggests five additional insights. First, certain genetic traits are likely to be correlated with other genetic traits. Second, a parent should choose a diversified portfolio of designer genes. Third, designer genes can be misunderstood and misused because of their complexity. Fourth, because of the asymmetric information between scientists and consumers regarding designer genes, a regulatory system of mandatory disclosure of risks and informed consent should complement professional codes of ethics and norms of behavior. Fifth, recent advances in computer and information technologies and increased globalization imply that any regulation of reprogenetic technologies must be sensitive to international and regulatory arbitrage.

Finally, the above decision traps and lessons from analogy to fi-

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122. *See* SCHELLING, *supra* note 19, at 91 (discussing tipping models).

123. *See* ANDREW MICHAEL SPENCE, MARKET SIGNALING: INFORMATIONAL TRANSFER IN HIRING AND RELATED SCREENING PROCESSES 122 (1974) (discussing signaling models).

124. *See* BRIAN STABLEFORD, FUTURE MAN 119-23 (1984) (discussing such possibilities).

125. *But see* Huang, *supra* note 102, at 1701 (demonstrating that incomplete commodification is an equilibrium outcome).

nancial engineering suggest an incremental approach to designer genes for parents and society alike. In closing, it should be noted that reprogenetic technologies offer us a challenge and an opportunity to make the world a better place for all humans. Whether we meet such a challenge successfully and utilize an opportunity to improve the human condition for ourselves and our progeny is truly up to us, individually and collectively.

APPENDIX. TWO HERD MODELS OF REPROGENETIC SELECTION

Game theory, more accurately described as multi-person decision theory, is a branch of applied mathematics having numerous applications in biology,[126] economics,[127] law,[128] management,[129] and politics.[130] This Appendix presents two related, but distinct, parsimonious game-theoretical models of herd behavior in reprogenetic selection. The models differ in the source of the herd behavior. In the first model, popularity is the driving force behind use of reprogenetic technologies. The benefit that any parent receives from using a reprogenetic technology increases with the proportion of other parents expected to use that reprogenetic technology. In the second model, status competition is the driving force behind use of reprogenetic technologies. The benefit that any parent receives from using a reprogenetic technology decreases with the proportion of other parents expected to use that reprogenetic technology.

Suppose that a society develops a specific type of reprogenetic technology that allows parents to choose a particular gene for their children. There is a private cost of *\$C* to parents for employing this particular sort of reprogenetic technology. The society is modeled as the unit interval: *[0, 1]*.[131] Assume that all parents face a binary decision of whether or not to use the reprogenetic technology. For simplicity, assume that all parents have identical preferences involving this reprogenetic technology.

In order to capture the herd-like component of traits valued for their popularity, assume that the payoff for using the reprogenetic technology in question depends on the number of others choosing to use this reprogenetic technology, but not on their identity. Let *P*

126. *See, e.g.*, KARL SIGMUND, GAMES OF LIFE: EXPLORATIONS IN ECOLOGY, EVOLUTION AND BEHAVIOUR (1993) (providing an exposition of game theoretic models of predator-prey, population ecology, molecular evolution, population genetics, sex, and reciprocity).

127. *See, e.g.*, PRAJIT K. DUTTA, STRATEGIES AND GAMES: THEORY AND PRACTICE (1999) (providing an exposition of applications of game theory to economics, particularly dynamic competition).

128. *See, e.g.*, Peter H. Huang, *Strategic Behavior and the Law: A Guide for Legal Scholars to Game Theory and the Law and Other Game Theory Texts*, 36 JURIMETRICS J. 99 (1995) (providing a review of the application of game theory to law).

129. *See* JOHN MCMILLAN, GAMES, STRATEGIES, & MANAGERS: HOW MANAGERS CAN USE GAME THEORY TO MAKE BETTER BUSINESS DECISIONS (1992) (providing an exposition of game theory for managers and business school students).

130. *See* JAMES D. MORROW, GAME THEORY FOR POLITICAL SCIENTISTS (1994) (providing an exposition of game theory for political scientists and graduate students in political science).

131. This technical assumption simply ensures that no individual decision-maker is "large" relative to society as a whole, so that no individual decision-maker's choice by itself affects the proportion of society making that choice.

denote the proportion of the society choosing to use the reprogenetic technology. Then, P lies in the closed interval $[0, 1]$. Suppose the net payoff or utility, U, to any parent for employing this particular reprogenetic technology is simply given by its benefits minus its costs, where the benefits can be decomposed into an absolute component, A, and a relative component, $R(P)$. Thus, $U(P) = A+R(P)-C$.

For a model of genes that parents desire for their children the more those genes become popular, assume the relative component has a multiplicative form $R(P) = RP$ with $R > 0$. This particular functional form means that the more other parents employ the reprogenetic technology in question, the more that an individual parent benefits from using it. This is the essence of the reprogenetic technology being valued because of its popularity. Thus, $U(P) = A+RP-C$.

Next, assume that $A+R > C$. This means that, if every other parent uses the reprogenetic technology, any particular parent must also use it just to "keep up" with the others. Formally, this assumption means that $U(1) > 0$. Furthermore, assume that $A < C$, for otherwise the reprogenetic technology has such large absolute benefits that even when nobody else uses it, any particular parent would choose to use it; that is, $U(0) < 0$. Let Π denote the proportion of society that a parent expects to employ this reprogenetic technology. As was true for P, Π lies in the closed interval between 0 and 1. Suppose the payoff for not using this reprogenetic technology is given by the equation: $B-HP$, where B stands for benefits $B > 0$ and the relative harm from not using this reprogenetic technology increases the more others use this reprogenetic technology, so $H > 0$. Parents make their decisions by comparing their expected utility from using this reprogenetic technology, namely, $EU = A+R\Pi-C$ with their expected utility from not using this particular reprogenetic technology, namely, $EU = B-H\Pi$.

In a rational expectations Nash equilibrium, the expected proportion of society choosing to use the reprogenetic technology must equal the proportion that actually chooses to use it, that is $\Pi = P$. It so happens there are several rational expectations Nash equilibria of this game. The first outcome, where nobody uses the reprogenetic technology (that is, $P = 0 = \Pi$) requires that $A-C < B$ or $A < B+C$. A second outcome, where everyone uses this reprogenetic technology (that is, $P = 1 = \Pi$) requires that $A+R-C > B-H$ or $A+R > B+C-H$. For both of the first and second equilibrium conditions to hold, it must be that $R > H$. The third outcome is where an intermediate proportion P^* of society uses the reprogenetic technology in question, while the proportion $1 - P^*$ does not use the reprogenetic technology. The critical value of P^* is solved for by setting the expected utility from using this reprogenetic technology equal to the expected utility from not using this reprogenetic technology.

Algebraically, this means that P^* solves this equation: $A+RP^*-C = B-HP^*$, which means that $P^* = (B+C-A)/(R+H)$. Only at that value of P^* is a parent indifferent between using the reprogenetic technology and not. This last outcome is a mixed strategy equilibrium in which some parents choose to use the reprogenetic technology and others do not. In the other two pure strategy equilibrium outcomes, all of the parents make identical choices regarding the use of the reprogenetic technology. Notice that $P^* > 0$ because $R > 0$, $H > 0$ by assumption, while $A < B+C$ is required for the first equilibrium. Also, notice that $P^* < 1$ because $(B+C-A) < (R+H)$ is equivalent to $B+C < A+R+H$, or $A+R > B+C-H$, which is already required for the second equilibrium.

In terms of social welfare analysis, each parent receives a utility of B in the first equilibrium $P = 0$, a utility of $A+R-C$ in the second equilibrium when $P = 1$, and finally a utility of $B-HP^* = A+RP^*-C$ in the third equilibrium when $P = P^*$. Because we know that $P^* > 0$ and $H > 0$, it follows that $HP^* > 0$ and, so, $B > B-HP^*$, meaning that all parents receive a higher utility in the first equilibrium than in the third equilibrium. Also, because we know that $P^* < 1$, it follows that $A+R-C > A+RP^*-C$, meaning that all parents receive a higher utility in the second equilibrium than in the third equilibrium. In other words, society is better off with either everybody or nobody using reprogenetics than if an intermediate fraction uses it. In general, it might be possible that there is not a social benefit from having a uniform population possessing the trait in question because of social costs in terms of diversity, tolerance, or even decreased evolutionary fitness. In this model, however, society is better off with either uniform non-use or uniform use of reprogenetics compared to an intermediate non-uniform use of reprogenetics. While we know that $A+R-C > B-H$ is required for the second equilibrium, it is indeterminate whether $A+R-C > B$. Thus, we have no general comparison of utilities between the other pairs of equilibrium outcomes.

Suppose that the absolute benefits to having a child are equal regardless of whether or not reprogenetics is used (that is, assume that $A = B$). Then, if and only if $R > C$ are parents better off in the second equilibrium than in the first equilibrium. Another way of stating this result is that if the absolute benefits of having a child are the same regardless of the use of reprogenetics, then society is better off when everybody uses reprogenetics for popular traits than if nobody uses it. This holds true if and only if the cost of reproductive technology is less than the multiplicative relative benefit factor to parents from using reprogenetics.

The above model assumed that the reprogenetic technology in question ensured that an individual possessed a particular trait valued for its popularity, such as right-handedness or a specific color of hair or eyes. This model can be revised to analyze genetic technology resulting in traits desired for their relative position, such as intelligence or body size and height. With such traits, there may not only be social pressure, but also a positional arms race to use reprogenetics to select higher and higher values of the physical or mental attributes in question. As with traits desired for their popularity, choosing to use this reprogenetic technology for traits desired for their positional value is individually rational. But, from the viewpoint of society, if the only reason parents are using this reprogenetic technology is to keep up with their neighbors, then society has not achieved any social benefit. After taking into account the private cost C of employing this reprogenetic technology, society is worse off. Parents are trapped in a reprogenetic "rat race."

A positional model of reprogenetics formally differs from a popularity model of reprogenetics only in the structural equation for the relative benefit from having a gene correlated with a positional trait, namely, $R(P)$ becomes the product of R and $(1\text{-}P)$ instead of the product of R and P. This particular functional form means that the more other parents employ the reprogenetic technology in question, the less that an individual parent benefits from using it. This is the essence of the reprogenetic technology being valued because of its correlation with a positional trait. Thus, parents receive a utility from using this reprogenetic technology given by the equation: $U(P) = A+R(1\text{-}P)\text{-}C$, where, as before, $R > 0$. As before, parents decide whether to use this reprogenetic technology by comparing their expected utility from using this reprogenetic technology, namely, $EU = A+R(1\text{-}\Pi)\text{-}C$, with their expected utility from not using this particular reprogenetic technology, namely, $EU = B\text{-}H\Pi$.

Also as before, in a rational expectations Nash equilibrium, the expected proportion of society choosing to use reprogenetics must equal the proportion that actually chooses to use it, that is $\Pi = P$. Let us examine the possible rational expectations Nash equilibria. For nobody to use the reprogenetics (that is, $P = 0 = \Pi$), it must be true that $A+R\text{-}C < B$ or $A\text{-}(B+C) < \text{-}R$. But, as $R > 0$ by assumption, $P = 0$ requires that $A\text{-}(B+C) < 0$. For everyone to use reprogenetics (that is, $P = 1 = \Pi$), it must be true that $A\text{-}C > B\text{-}H$ or $A\text{-}(B+C) > \text{-}H$. For both of the first and second equilibrium conditions to hold, it must be true that $\text{-}H < \text{-}R$ or $H > R$. An outcome where an intermediate proportion P^* of society uses reprogenetics, while the complementary proportion $1–P^*$ does not use reprogenetics, requires finding a critical value of P^* that is solved for by setting the expected utility from using this reprogenetic technology equal to the expected utility from not using it.

Algebraically, this means that P^* solves this equation: $A+R(1\text{-}P^*)\text{-}C = B\text{-}HP^*$, which means that $P^* = [A+R\text{-}(B+C)]/(R\text{-}H)$. Only at that value of P^* is a parent indifferent between using reprogenetics and not using it. Notice that, for $P^* > 0$ to hold if $H > R$, which is required if both of the polar cases $P = 0$ and $P = 1$ are to be viable, then it must be the case that $A+R < B+C$, or $A\text{-}(B+C) < \text{-}R$, which is the condition that is already required for the $P = 0$ equilibrium. Thus, an equilibrium in which nobody chooses to use reprogenetics is consistent with an equilibrium in which an intermediate fraction chooses to use reprogenetics. However, notice that $P^* < 1$ requires that $A\text{-}(B+C) < \text{-}H$, which is inconsistent with the condition that $A\text{-}(B+C) > \text{-}H$, which is already required for the $P = 1$ equilibrium. Thus, an equilibrium where all choose to use reprogenetics is inconsistent with the outcome where some intermediate fraction uses the reprogenetic technology. To summarize, both of the pure strategy equilibrium outcomes $P = 0$ and $P = 1$ can coexist, but the later is inconsistent with a mixed strategy equilibrium, while the former can coexist with a mixed strategy equilibrium.

In terms of social welfare analysis, each parent receives a utility of B in the first equilibrium when $P = 0$, a utility of $A\text{-}C$ in the second equilibrium when $P = 1$, and finally a utility of $B\text{-}HP^* = A+R(1\text{-}P^*)\text{-}C$ in the third equilibrium when $P = P^*$. Because we know that $P^* > 0$ and $H > 0$, it follows that $HP^* > 0$ and so, $B > B\text{-}HP^*$, meaning that all parents receive a higher utility in the first equilibrium than in the third. Also, because we know that $R > 0$ and $P^* < 1$ or $(1\text{-}P^*) > 0$, it follows that $R(1\text{-}P^*) > 0$ and $A\text{-}C < A+R(1\text{-}P^*)\text{-}C$, meaning that all parents receive a lower utility in the second equilibrium than in the third (even though both of these outcomes cannot exist for the same set of parameters). Thus, society is better off if nobody uses reprogenetics than if an intermediate fraction uses it, but better off if an intermediate fraction uses it than if everybody uses it.

Finally, while we know that $A\text{-}C > B\text{-}H$ is required for the second equilibrium, it is indeterminate whether $A\text{-}C > B$. But, again, if we suppose that the absolute benefits of having a child are the same whether or not reprogenetic technology is employed (that is, assume that $A = B$), then, because we also assumed that $C > 0$, parents are better off in the first equilibrium than in the second. Another way of stating this last result is that if the cost of reprogenetics for a positional trait is positive (as is likely to be the case), then society is better off when nobody uses reprogenetics than if everybody uses it.