

In 100 years

By Alvin E. Roth

January 2012

For those of you reading this in 2112, let me introduce myself by saying that in the late 20<sup>th</sup> and early 21<sup>st</sup> centuries I studied the design of matching markets, which are markets in which price alone doesn't clear the market, and so participants can't just choose what they want (even if they can afford it), they also have to be chosen. These are markets that involve application or selection processes or other forms of courtship. Matching markets determine some of the most important events of our lives: where we go to school, who we marry, what jobs we get, even whether we get a lifesaving organ for transplant if we should happen to need one (see Roth 2002, 2008 for overviews). So I'll concentrate my predictions on these things, namely schools, jobs, marriage and family, and medicine, along with some thoughts about the possible state of economic expertise, i.e. the things that economists produce and sell.

Part of my prediction technique will be to think about which aspects of those things may have, in 100 years, become commodities which can be had by anyone who has the price and wants to buy them, and which things will continue to be allocated by matching markets in which each side of the market has to choose and be chosen by their counterparties on the other side.

I've also spent some time studying how some kinds of transactions are regarded as repugnant, in some times and places, and how this constrains what markets we see (Roth 2007, Leider and Roth 2010). By a repugnant transaction I mean a transaction that some people would willingly engage in, but that others wish to prevent. Over the long sweep of history, some formerly repugnant transactions have come to be regarded as ordinary, while other ordinary transactions have come to be regarded as repugnant, often with important consequences. For example, charging (and paying) interest on loans was for centuries regarded as repugnant, but no longer is for most of the world (although Islamic law still forbids it). It is hard to imagine how the global markets for capital and the economic activity they support would have developed if interest were still repugnant. On the other hand, where markets for slaves once thrived, they are now repugnant. Slavery and other forms of involuntary servitude, including servitude initially entered into voluntarily like indentured servitude, are now illegal in most of the world. This is notable not least because entering into indentured servitude was once the most common way of purchasing passage across the Atlantic Ocean to America. (And, although this is no longer a legal contract, there are still black markets in which illegal immigrants essentially indenture themselves in return for being smuggled into the United States.) So I'll also try predicting some currently repugnant transactions that may not be repugnant in 2112, and I'll speculate about some transactions we now see that may become repugnant.

There are several ways to go about making predictions, but surprising predictions for 100 years in the future are inevitably little more than guesses, maybe educated guesses. The most reliable prediction method for the short term is to extrapolate current trends, and this may serve for the long term as well, supplemented by guesses at as yet unrealized consequences of those trends that will be realized as they progress. Somewhat more risky is to guess which current trends will run their course and be only a

memory. And guesses about what entirely new developments will emerge are close to science fiction, since the nature of really new developments (e.g. anti-gravity machines, contact with extra-terrestrial intelligence) is that we have little on which to base our guesses. But we can confidently predict that some very unpredictable developments will have an outsized influence in 100 years, just as antibiotics and integrated circuits and the rise and fall of totalitarian ideologies have influenced life in the last hundred years in ways that couldn't have been predicted in 1912. So I won't attempt to guess at the really unpredictable. Instead, extrapolation will make up the bulk of my predictions, but I'll also take a stab at predicting that the trend towards devoting an ever larger proportion of resources to medical expenditures will eventually reverse itself, although predictions of that sort don't have a high success rate (e.g. Malthus predicting famine because population growth just couldn't continue...).

To set the stage, I think the biggest trend of future history (if it is not disrupted by environmental catastrophe, or descent into widespread terrorism or warfare with weapons of mass destruction) is that the world economy will continue to grow and become more connected. Material prosperity will continue to increase, population will grow, and healthy longevity will increase.

While increased prosperity will not eliminate competition, it will give people more choices about whether and how hard to compete. Many will opt to begin on a slower track, spending more time accumulating youthful experience prior to the assumption of a full set of adult responsibilities marked by completion of full time education, careers, marriage, and children. Retirement will also be a longer part of a productive life, and new forms of retirement will emerge, combining work and leisure and study and philanthropy.

Despite the increase in prosperity, some goods, services, statuses, knowledge still will be scarce. People who don't wish to settle for the simple life will continue to have incentives to strive and compete.

For those who wish to compete, there will be technological developments that enhance competitiveness, and allow them to work harder than ever. Some of these, like performance enhancing drugs, are beginning to be available today but are widely regarded as repugnant. That repugnance seems likely to fade. Other technologies, which we begin to glimpse as possibilities today, like selecting the genetic characteristics of our children, may remain repugnant and illegal, but nevertheless become widely available and tempting.

We already see performance enhancing drugs used in competitive sports, despite being widely banned. But while we may continue to try to cancel sporting victories won with the assistance of drugs, we are unlikely to decline cancer cures or software or theorems produced with the assistance of drugs that aid concentration, or memory, or intelligence. Safe performance-enhancing drugs may come to be seen as akin to good nutrition (much as we think children should drink milk) and to fashionable behavior (much the way we like good coffee today). And, just as drugs may already not be optional to reach the highest level in some competitive sports, they may not be optional in future competitive careers. When assistant professors of economics in 2112 fall behind their expected production of an article a week, their department chair may suggest that they increase their dosage of creativity enhancing or attention focusing pharmaceuticals to increase their chance of tenure. And some drugs—memory enhancers,

say—may be seen not as performance enhancers but as cures for things we didn't previously think of as diseases (much as erectile dysfunction came to be seen as a disease once it could be treated with pharmaceuticals). In 2112 our descendants will have trouble remembering a time when it was hard to remember the names of all the people you met, just as they may find it hard to understand why it was hard to run marathons on two consecutive days.

Similar to the way drugs will allow us to improve our own performance, increased understanding of genetics and reproduction and fetal development will allow parents to select or manipulate some of the genetic endowment of their children. Some of these options will remain repugnant even as they become more widely available, while others may come to be seen as part of careful child rearing. To the extent that these technologies are subject to legal limitations in some places and not in others, they will help fuel an international market in reproductive technology, as some parents travel to places that will cater to their desire to enhance the abilities of their children. We already see the beginnings of such a market, as access to fertility treatments, and markets for eggs and sperm and surrogate wombs are more available in the United States and India than in many places, and consequently draw "fertility tourists."

This trend will continue, and various reproductive options will become largely commoditized, and separated from sexual intercourse (not to mention traditional heterosexual marriage) and the need to be matched with a biologically appropriate willing co-parent. This will, incidentally, help facilitate nontraditional forms of marriage and child rearing, as well as delayed marriage and single parenthood, and many of these alternative arrangements (e.g. same sex marriage and polygamy) will no longer be regarded with the repugnance and legal barriers that still greet them today in many places, just as many if not most forms of consensual sexual relations between adults are no longer today regarded in many places with the repugnance of centuries past.

Despite the commoditization of reproductive services, I expect that families will remain one of the main units of production—certainly of children—and of consumption of all sorts of household goods and comforts. Long-term (even if not lifetime) relationships will remain important as work and play are increasingly globalized, so that personal fixed points become a larger part of peoples' sense of who they are (and see infectious diseases below for possible continuing effects on sexual fidelity). But in the other direction, generations will be longer and child rearing will take up a smaller proportion of longer healthy lifetimes, which may make divorce more common, and perhaps lead to new forms of polygamy-over-lifetime relationships to supplement the serial monogamy that sometimes today accompanies high divorce rates.

Not only drugs will enhance performance, but, less controversially, so will increasingly powerful and personal computation. But this will lead to rising concerns about personal data and privacy, and certain kinds of transactions involving personal data that are not yet repugnant may become so. For example, as personal data become increasingly valuable for business purposes, such data may also come to be viewed more like intellectual property, with protections akin to patent and copyright protection today, moderated by "fair use" exceptions, so that uncompensated use of transactional data may come to seem repugnant, or at least subject to limitations. Already in 2012 there are consensual transactions in

personal data, e.g. when supermarket customers are offered compensation in the form of discounts for allowing their identity to be linked to their purchases as their barcode data is collected at the cash register, while uncompensated uses of data generated through various transactions are coming under scrutiny, particularly when there is doubt that appropriate consent can be given.

More importantly, data may become a civil rights issue. Today my smart phone gives me the internet in my pocket, but well before 2112 the camera in my contact lens should be able to use face recognition software to search vast databases and display for me a great deal of data about the people I see. This will change the meaning of “search,” perhaps shifting the balance between the word that today indicates what we do with Google, towards the more legal meaning of what police do when they enter your home with a warrant. That is, when I can glance at you and have immediate access to all your available data, guarding those data may become increasingly important. Already today we generate a data stream through our purchases and travel and encounters with many levels of bureaucracy (from marriage records to police and court cases). Much of this is public, and much more of it is electronically searchable by those with access. Laws defining who has access to what data about individuals under what circumstances will likely become increasingly important, and all kinds of data may be subject to restrictions about its sale or transfer, with some transactions coming to be regarded as repugnant and increasingly regulated if not prohibited by law. We have already begun to see this beginning with medical records.

Which brings us to medicine, which will likely be as different in 2112 from today as today’s medicine is from 1912. Some medical and public health advances will be against predictable physical failings—e.g. heart attacks and many more cancers will be curable or avoidable. There may also be setbacks: one of our greatest advances of the last hundred years, the development of antibiotics and vaccines, may come to be seen as having reached and receded from a high water mark. Infectious diseases may have a renaissance, as evolution creates drug-resistant bacteria or vaccine eluding viruses, while increased globalization facilitates the rapid spread of infection around the world. To the extent that infectious diseases remain dangerous, sexually transmitted diseases may, in 2112, have mediated changes in social conventions about love and marriage and further changed some of the tradeoffs between sexual fidelity and promiscuity. These changes may be particularly important if they interact with how many children people choose to have.

Some of the big (but hard to predict) changes in medicine will be technological. For example, I have worked on developing kidney exchange networks that increase the number of kidney patients who can receive transplant organs from living donors. I bet that by 2112 the whole idea of cutting a kidney out of one person and sewing it into another will seem like an ancient barbarity. But it’s hard to guess whether transplantation will have been replaced by xeno-transplantation to give you a working kidney grown in a farm animal, or stem cell therapies to grow healthy new kidneys of your own, or artificial kidneys, or simply better treatment of diseases that now cause kidney failure.

Many of these alternatives may be both longer lasting and cheaper than transplantation. This is what makes me think that, while medicine *could* continue to be an ever growing part of the economy as the population gets older, it also could (sweet thought) become like farming, so efficient that a smaller part

of the economy provides all of it that we need. If progress in preventive medicine keeps pace with other advances, and we come to spend most of our lives as healthy as 20 year olds, and then expire peacefully at home, it could be that doctors, like farmers, will meet our needs as a much smaller industry that mostly produces products out of commodity-like inputs, that can be assembled into personalized packages, much as people in the developed world today enjoy a wide variety of year-round agricultural commodities that would have been beyond the reach of all but the very richest people in 1912

I spoke above about how performance enhancing drugs may become essential for professors seeking tenure. Of course, tenure may be increasingly concentrated at elite universities, which will remain recognizable by their high tuition together with abundant financial aid to support expensive teaching in residential communities of scholars, to which admission is selective. Despite the fact that information itself will be increasingly available elsewhere, elite universities will persist for much of the same reasons that cities will, including not only information transmission but also signaling and networking for various purposes, including matchmaking. High education couples will continue to pair off, but people pursuing high intensity careers may marry those pursuing lower intensity careers as mobility and long hours continue to be important in competitive careers. As marriage is delayed, the post-graduation educational network may become more important for this, and perhaps we will see new kinds of matchmaking.

Nevertheless, elite universities, and residential campuses will continue to become smaller parts of the education industry. (A related possibility is that the world's fanciest universities will continue to open branch campuses around the world, and that this will serve to foster really good distance education with professors in one place lecturing to many students by electronic means, with students able to interact with each other as if they were in one location.) There will be lots more access to information/education on demand, without the logistical constraints of conventional classes and courses. The trend towards more diverse kinds of education will continue. Mass post-secondary education will continue to evolve, perhaps with electronic outsourcing of particular workforce related kinds of education and training. So those parts of post secondary education most closely connected to specific job related skills will likely become more decentralized and commoditized and electronic, even while elite universities remain very recognizable, as universities in 2012 would be quite recognizable to students and professors from 1912, despite big changes, many of which—e.g. computers and electronic communications—are reflections of how those have changed society in general, rather than reflections of a change in universities' role in society.

But for those who can gain access to it, several years of study in comfortable surroundings will remain a desirable way of accumulating human capital while preparing for and connecting with the adult world. This may continue to become a social marker that will to some extent supplant socio-economic status. In the U.S. presidential election of 2008, in which the candidates were Barack Obama and John McCain, the candidate who was a multimillionaire by marriage and the son and grandson of admirals tried with considerable success to cast the graduate of Columbia and Harvard as a representative of the elite.

But teaching and networking aren't the only things that go on at universities; they are also the bastion of investigator-initiated basic research. As technology advances, commercial research and development

will continue to grow in importance, but universities will remain important for basic research. Here too, networks will remain valuable for introducing and validating scholars, even while physical proximity becomes less critical. Already in 1990 I was a coauthor of a paper in which my coauthors didn't all know one another, and in 2012 much less of my communication with coauthors is face to face than when I began to do research in the 1970's. However it is still the case that most of my collaborations begin with face to face interaction. As the quality and ease of distance communication improve, this may become a quaint antiquity, in which case research collaborations should become ever more common across the boundaries of particular universities, and between university-based scholars and those at other kinds of institutions.

This brings me to predictions about the work that economists do. Economics will still be at the vanguard of social science, partly because it will continue to incorporate insights and data that were once seen as sociology and political science, just as it has already begun to assimilate insights from psychology, as well as biology.

Poverty will remain (development will still be a field of economics), but poverty in the developing world 100 years from now may look more like poverty in the developed world today, or perhaps the poor in the developing world will have the material prosperity that the middle class do in the developed world today, especially since many of the markers of what used to be middle class prosperity will grow cheaper, much as telephones and televisions and computers have already. Consequently, development economics will be more closely integrated with the rest of practical and academic economics than it is today.

One important change in the economy will be in the kinds of marketplaces that will become available. As markets have become more computerized (and as we have started to understand better what well designed marketplaces do), "smart markets" have already become possible that do some of the work that market participants formerly had to do. For example, bidders in eBay auctions can submit reservation prices to a software proxy agent, and participants in school-choice or labor-market clearinghouses can submit preference lists, and in each case the market uses that information on the participant's behalf, without requiring further attention. That is, computers have already in 2012 increasingly become an important part of markets and marketplaces, from the computerized cash registers that also help stores monitor inventory, to the computerized stock exchanges that let trades be executed ever more quickly, to the smart markets that start to verge a little on artificial intelligence, acting as proxies for individual agents, and using the information submitted on behalf of agents to compute outcomes that couldn't have been found in markets run without computers (think combinatorial auctions, and stable matching mechanisms).

As computers and computer science continue to advance, artificial intelligence will have crossed the barrier so that some parts of technology will be self-directing, i.e. able to operate not merely without direct human supervision but able to formulate intermediate goals as well as plans of action to achieve them. Artificial intelligences may become companions (distant descendants of today's iPhone games), friends, and advisors (distant descendants of today's GPS navigation advisors that can sound disappointed when we miss a turn), and market intermediaries. As computer assistance becomes more

ubiquitous in all aspects of life, some of that assistance will be in markets, helping us piece together things we need (such as airline, hotel, and rental car reservations for different legs of a multi-part journey) the way a skilled assistant would today, without the time consuming personal attention that some person would have to give to the task today. The next step will be to have our proxies help us decide which trips to take, e.g. which seminar and conference invitations to accept, and how to schedule them and structure the journeys involved, while our proxies interact with the scheduling proxies of the seminar and conference organizers. (As suggested above, I'm guessing that some seminars and conferences will still involve travel, although electronic communications will have made it unnecessary for the seminar presentation itself, the after-seminar dinner and the exchange of ideas it fosters, not to mention the matchmaking among similarly inclined investigators and potential coauthors, may still be better in the flesh.)

Computerized markets will make market design more important, as many market details will have to be embodied in computer code. But many kinds of market design that are today crafted by specialists will have passed from frontier knowledge to whatever is then the equivalent of shrink-wrapped software, much the way that techniques of mathematical optimization that once were the domain of Ph.D.s in Operations Research have become available in software packages. But there will still be unsolved problems of organization and coordination, so market design (or more generally, *design economics* dealing not just with markets but with the design of all forms of organizing and transacting and allocating) will have become and will remain an important part of economics. And some of what economists do will have come to be regarded as engineering—it won't be surprising to anyone in 2112 that questions of e.g. how to organize school choice are handled better than they were in 2012, just as it won't be surprising that bridges are lighter and longer, even if some of the underlying economic and physical principles have been well understood for a long time. Other kinds of advances will have produced better ways to apply those principles.

To summarize the predictions I've made here about 100 years from now, I think that the trend of increasing prosperity will continue, but that it will not necessarily (as Keynes predicted in 1930) bring us all lives of leisure. Many will work harder than ever, and some of the things some of us will do to work more efficiently—like taking performance enhancing drugs--will go from being repugnant today to ordinary in the future. Other things we do eagerly today, like use computers for access to more and more data, may become repugnant in some respects, as privacy of personal data moves to the forefront of civil rights issues. And while medical advances will continue on all fronts, and advances in preventive medicine will make medical care and long-lived good health more widely available, some kinds of medicine, including reproductive medicine along with other aspects of reproduction, will become commoditized, while others, such as genetic manipulation of various sorts, may become repugnant. Some kinds of education will become commoditized, but among the matching markets that we see today, selective admissions to elite universities will remain, as will networking and matchmaking for family formation (under a wider variety of marital forms) and perhaps increasingly, for research collaborators and other kinds of business partners. And there will still be economists, and economic mysteries to unravel, including those that will arise from the increased computerization of markets and marketplaces. Much of market design that we struggle to understand today will have become

commoditized and be found in off the shelf software, but understanding how to design novel markets and fix market failures will remain an active concern of our economist grandchildren.

Keynes, in writing about the future of economics, said “If economists could manage to get themselves thought of as humble, competent people, on a level with dentists, that would be splendid!” Perhaps if we replace “dentists” with “engineers,” that is still a good goal for the next hundred years.

#### References

Keynes, John Maynard (1930), “Economic Possibilities for our Grandchildren”, *Essays in Persuasion*, New York: W.W.Norton & Co., Leider and Roth 2010

Roth, Alvin E. “The Economist as Engineer: Game Theory, Experimental Economics and Computation as Tools of Design Economics,” *Econometrica*, 70, 4, July 2002, 1341-1378.

Roth, Alvin E. “Repugnance as a constraint on markets,” *Journal of Economic Perspectives*, 21(3), Summer, 2007, 37-58.

Roth, Alvin E. "What have we learned from market design?" Hahn Lecture, *Economic Journal*, 118 (March), 2008, 285–310.