A Monetary Market for Kidneys*

Mohammad Akbarpour† Farshad Fatemi‡ Negar Matoorian§

July 2018

Preliminary draft. Data permissions are being processed. Hence, please do NOT circulate!

Abstract

This paper studies the Tehran monetary market for kidneys, which is the largest (legal) monetary market for kidneys in the world. We make several contributions: First, we document the institutional details of the marketplace through primary source interviews. Next, using a new dataset of the market, we show that the average waiting times in live and deceased queues are less than one year and nine months, respectively. There is a substantial supply of living paid donors who are fairly price-elastic, while the paid market has almost completely crowded out altruistic donation. In addition, trends in waiting times suggest that a monetary market can make all patients better off, including those who do *not* purchase live kidneys, because of the reduced congestion of the deceased queue. We then build a dynamic model of the market with two queues and employ it to estimate a lower-bound for the welfare gains of legalizing kidney sales. Our results suggest that, if a market for kidneys in the U.S. leads to waiting times similar to those in Tehran, it can increase patients' welfare by at least $14 billions per year, and can save more than $8 billions in annual healthcare costs. We close by examining some ethical concerns of this market through the lenses of our data.

Keywords: Kidney, Market, Transplant, Repugnance, Waiting list, Congestion.
JEL Classification Codes: D85, C72, L14, Z13

*We would like to thank Al Roth for several conversations. We also thank Amir Kermani, Matthew Gentzkow, Michael Ostrovsky, and several seminar participants for valuable feedback.

†Graduate School of Business, Stanford University. Email: mohamwad@stanford.edu.

‡Graduate School of Management and Economics, Sharif University of Technology. Email: ffatemi@sharif.edu

§Department of Economics, Stanford University. Email: negarm@stanford.edu

1 Introduction

In every country - except one - patients with end-stage renal disease (ESRD) have two legal ways to have a kidney transplant. The first one is to find a friend or family who is willing to donate a kidney to them. The second way to get a kidney transplant is to join the waiting list for a deceased kidney. It is hard to exaggerate the dismal state of ESRD patients in the world. By the end of 2017 and only in the United States, more than $100,000$ patients are waiting to receive deceased kidneys, a number that has been steadily growing for more than a decade. In 2017, more than 35000 patients were added to the waiting list, but there were only enough kidneys to perform about 20000 transplants. Consequently, more than 4000 patients died and more than 3000 patients became too sick to have a transplant, all waiting for a kidney that never arrived. In fact, the median waiting time to receive a transplant is more than 42 months and, depending on blood-type and geography, it is sometimes several years longer. Such long waits increase the likelihood of post-transplant complications and impose substantial costs on society – ESRD costs American taxpayers nearly 50 billion dollars per year.

Increasing the supply of available kidneys for transplantation would extend the quality adjusted lifetime (QALT) of patients by several years. In addition, it would ease the suffering of patients who endure long waits under dialysis, and it would likely save the society billions of dollars. Consequently, a great deal of resources have been devoted to finding solutions to increase the supply of organs and improve their allocative efficiency.[1] While these efforts have led to many success stories, they are far from closing the gap between supply and demand for transplantation. For instance, the total number of transplants facilitated by kidney exchange in the U.S. in 2017 was less than 1% of the number of patients who are waiting for a kidney

Any persistent supply-demand gap leads to a natural economic question: What are the obstacles to equilibrating supply and demand in that market? In the case of kidneys, the answer is clear, since using financial incentives to acquire kidneys is banned in nearly all countries of the world, which in turn limits the supply of live donors to altruistic donors.

Given the dismal state of the kidney crisis, is it now the time to consider compensating donors? This question is the subject of an ongoing debate within the medical, social sciences, and ethics communities. The debate, however, has been largely based on theoretical arguments and some speculations, as opposed to evidence. This is not surprising since running an "experiment" to provide empirical evidence for this topic is virtually impossible.

[1] The proposed solutions include marketing campaigns to encourage deceased donation, building platforms to facilitate kidney exchange (Roth et al., 2004), optimizing the allocative efficiency of such exchanges (e.g. see Roth et al. (2005)), and, more recently, creating a global kidney exchange system (Rees et al., 2017; Nikzad et al., 2017).

Iran is the only country in the world with a legal, monetary market for kidneys. This paper is the first to introduce and exploit six years of data from a comprehensive dataset of the largest regulated market for kidneys in Iran (the *Tehran* market) to shed light on several aspects of a regulated kidney market.

We start by reviewing the history of the Iranian market in Section 2. In Section 3, we describe institutional details of the marketplace, including the matching process and the compensation package. This section is written based on primary source interviews and participating in the marketplace day-to-day activities in person. Section 4 presents several important stylized facts about the outcomes of the marketplace. First and foremost, there is a substantial supply of paid donors who are highly price-elastic. Thus, the average time patients wait to receive live and deceased kidneys are around 320 and 260 days, respectively. Second, more than 85% of paid donors are from households with wealth levels below the median. Third, patients who purchase live kidneys are on average richer than those who receive deceased kidneys. Finally, less than 2.3% of transplants are from altruistic living donors, which suggests that the existence of a legal market has almost entirely crowded out altruistic donation.

We create a dynamic model of the Tehran market in Section 5. The model includes two queues, one for deceased donors and one for living paid donors. Patients are heterogeneous in their wealth levels (captured by their marginal values for money). Upon entering the system, they choose one of the two queues by solving a dynamic utility maximization problem. Agents' utilities depend on waiting times in each queue, as well as the regulated price of kidneys. Waiting times, in turn, are endogenously determined by the choices of patients, as well as the supply of living donors. Our first characterization result shows that there is a cutoff type such that patients above the cutoff (poorer patients who have higher marginal value for money) choose the deceased queue and patients below the cutoff type (wealthier patients) choose the live queue.

Our main theoretical result in Subsection 5.1 shows that legalizing kidney sales makes *all* patients weakly better off, even those who do receive a deceased kidney. The (*ex post* obvious) intuition of this result is that patients who choose to purchase kidneys in the monetary market decrease the congestion of the deceased queue, which reduces the expected waiting time of this queue, which in turn makes patients who receive deceased kidneys better off.

We continue by calibrating the model to provide some rough estimate of the welfare gains in Section 5.2. We first argue that a lower-bound on a patient's utility is the value she gets from choosing the deceased queue upon her arrival, since by revealed preference all patients who choose the live queue must be getting a higher utility. Our conservative estimates show that a single patient's welfare gains from Tehran market is at least 8% of the QALT value of

a deceased kidney. There are not reliable estimates of this value in Tehran, but the medical literature

Our next calibration exercise examines the following counterfactual: Suppose kidney sales are legalized in the U.S. and the insurance companies (or the Medicare, as in dialysis) pays for the cost of the purchased kidneys. Also, suppose the supply of live kidneys is at least $18,000$, which we show it can reduce the average waiting time of the deceased queue to levels similar to the Tehran market. How much are the welfare gains of this market for the patients? Using the previously established lower-bound, we show that legalizing kidney sales can increase the welfare of each U.S. patient by 0.58 of the QALT value of a deceased kidneys. Using the values estimated in Held et al. (2016), this translates to nearly $14 billion dollars of welfare per year. In addition, the reduction in waiting times would save the American healthcare system more than $7 billion dollars annually.

After analyzing the market from an economic perspective, we turn to the question of why kidney markets are illegal in nearly all countries of the world. We discuss a series of concerns related to this "market aversion" in Section 6. Some of these concerns can be addressed by careful regulation. For instance, the concern that only wealthy patients can afford live kidneys can be addressed by making the government the only entity that is legally allowed to purchase kidneys. The obtained kidneys can then be allocated to patients in a way similar to the allocation of deceased donors. This market design ensures that all patients have equal access to live kidneys. However, some concerns of legalizing kidney sales are not amenable to regulation. For example, the Catholic Church has expressed that compensating kidney donors inherently diminishes human dignity to a level that such markets should not be endorsed even if they are carefully regulated (Roth, 2015). Thus, our goal here is not argue that legislators should legalize kidney sales. What is crucial nonetheless is that the ongoing debate around monetary kidney markets must be informed on the likely welfare losses of banning kidney sales. This paper takes one step towards achieving this goal.

2 Institutional History

The first kidney transplant in Iran took place in 1967. Kidney transplantation was extremely rare in Iran for about two decades – less than 100 transplants were performed between 1967 and 1979 (Ghods and Savaj, 2006). The following decade was an arduous one for Iran. The 1979 revolution was followed by sanctions and an eight-year war with Iraq, resulting in hundreds of thousands of lost lives and a destroyed infrastructure. One consequence of such dismal situation was that hemodialysis became extremely rare and expensive.

In 1980, the Ministry of Health and Medical Education started supporting patients with living related donors to receive transplants abroad in a program by funding their travel and

transplant costs. In the following five years, a few hundreds of patients traveled abroad and received renal transplant. The high expenses of this program prompted the Iranian authorities to establish two domestic renal transplant centers between 1985 and 1987.

Despite the establishment of domestic centers, a vast majority of kidney patients could not have a transplant, mainly because an infrastructure for a deceased donor waiting list did not exist, and most patients did not have a living related donor. The government responded to this shortage by setting up the living unrelated donor (LURD) program in 1988. In this program, the government compensated the donors for their "altruism." The payment to donors was referred to as the *gift for altruism*. Later, an additional transfer from recipients to donors was included in the compensation package, which we will discuss in the next section. Following this new policy, there was a considerable increase in the number of transplantation centers, as well as in the number of transplants, which substantially decreased the death rates and the average waiting times of of the ESRD patients.[2]

The next important change happened in the April 2000, when the parliament passed the Organ Transplantation and Brain Death Act, legalizing deceased organ donation. Since then, the share of transplants from deceased donors has been steadily increasing. Today, more than 50% of transplants are from deceased donors.

3 Marketplace Rules

We now describe the institutional details of the Iranian system of paid donation, with a particular focus on Tehran market. The content of this section is based on a sequence of first-hand interviews of one of the authors[3] with the managers of the marketplace and several transplant surgeons in Tehran.

The *Kidney Foundation* of Iran, a charity founded and run by kidney patients, is the main operator of the kidney market in Iran. It has more than 137 branches all over the country. Each center keeps waiting lists for patients with different blood types (O, A, B, AB). They match donors of each blood-type to the patients of the same blood-type. There does not exist a country-wide centralized waiting list. The overall system of all branches are similar, but they differ in some details. The rest of this section describes the rules of marketplace in Tehran[4].

Kidney patients are referred to the Kidney Foundation through their personal physician

[2]Ghods (2002) and Ghods and Savaj (2006) claim that "by 1999, the renal transplant waiting lists in the country was eliminated successfully." These studies do not report the exact waiting times. As we will discuss soon, our data shows that the waiting list is not totally eliminated in the past six years.

[3]Farshad Fatemi.

[4]There is only one place in which the rules are totally different: The province of Fars recently banned kidney sales in the province. Shiraz, the most populated city of the province, hosts one of the largest transplant centers of Iran.

for either dialysis or transplant. An ESRD patient who is medically ready for transplant can choose to continue dialysis or to have a transplant. In the latter case, she has three options: (1) She can receive a kidney from a family member, or (2) to enter the Kidney Foundation waiting list in a center nearby their residential address to purchase a kidney, or (3) to enter the deceased donors waiting list.

Potential donors enter the market by registering in any of the offices of the Kidney Foundation. The registration is free of charge for both patients and donors. Donors' age must be between 18 and 35 and they must have a letter of consent from their spouse, if they are married, or their father, if they are not. The donors are referred to a psychologist to evaluate their mental health, and to inform them about the medical costs and risks of donation. After the initial official paperwork, and if they pass the psychic tests, donors are referred to a clinic for the initial medical tests. The initial tests determine both the blood-type and tissue type of the potential donor, and whether he has any sort of kidney problem or other health issues. If tests find the possibility of harm to the donor during or after the surgery, the donor is not allowed to continue the process.[5]

The matching process. Patients are served (essentially) based on a *first-come first-serve* basis. However, a patient is given priority in the waiting list if she is in medical emergency, as assessed by her physician. All patients should register in the institute and get matched through the centralized process – in particular, if patients search for a paid donor outside the market, they cannot sign a legal contract. After a donor passes the initial tests, the administrators contact the first patient in the same waiting list as the donor's blood type. They will then perform additional tests and evaluations of the tissue type compatibility. A higher level of the tissue-type match helps the transplanted kidney to last for a longer period of time. If the cross-match test results are negative (again, as assessed by the patients' physician), the next patient is called and the tests are run for the new patient and the same potential donor.

The donor and patient are required to have the same citizenship. This regulation is in place to prevent "kidney tourism."

Compensation. Once a patient and donor are biologically compatible, they sign a contract. Patients pay the *regulated kidney price* to the donor. Let p denote this price. This price was set at 90 million Rials from March 2011 to March 2015, and then was increased to 140 million Rials, which is the regulated price in December 2017 as well. Importantly, this price is independent of the blood-type. The government supplements the regulated price by

[5]There is no data on the percentage of donors who eventually pass the tests, but marketplace organizers claim that more than 50% of the donors do *not* pass the tests.

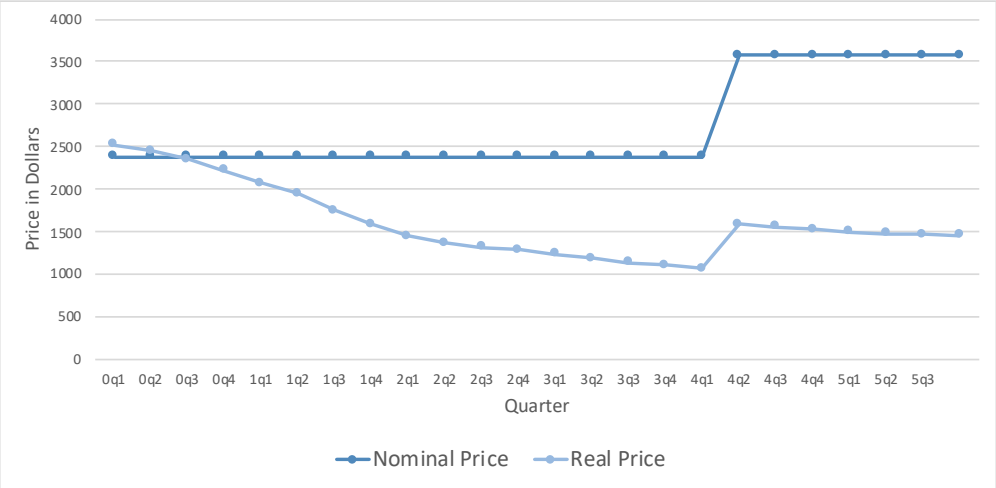


Figure 1: Nominal and Real (inflation adjusted) price of kidney over time

the 'gift for altruism', which we denote by s. The total payment to donors is $p + s$. This supplement has been fixed at 10m Rials and one year of free health insurance and has not changed since the marketplace has been around.

To make sense of these prices for the readers not familiar with the Iranian economy, from now on we state prices using U.S. dollar as the unit of currency.[6] In particular, we use the official exchange rate of dollar to Rial. As of July 2018, 1 dollar translates into 42,000 Rials. Hence, the price of kidney in different time periods is as reported in Figure 1:

In the past, patient and donors could negotiate for a "side payment" on top of the regulated price. The kidney foundation does not allow for such negotiations in the period of our data. The degree at which this is enforced is unclear. There are two pieces of evidence that suggest this might indeed be the case. First, if a patient reports such a request by a donor to the foundation, that donor is not allowed to sell anymore and if this happens after the biological compatibility is approved, the donor should pay a penalty.[7]. Second, the substantial increase in the supply of kidneys after the price increase of March 2015 also suggest that the regulated price is likely to be a binding constraint. We will therefore assume in our theoretical analysis that the regulated price is the actual price.

Technically, the patient pays for the cost of tests, surgical operations, after surgery cares, and immunosuppressive drugs. Nevertheless, ESRD patients in Iran are classified as 'Patients with Special Diseases' who are eligible for a government-funded medical insurance. Consequently, almost all recipients have access to immunosuppressive drugs for free and the government covers the medical costs of the transplant in public hospitals.

[6]Readers interested in the purchasing power parity equivalent of these prices can multiply these numbers by roughly 4. The annual minimum wage in Iran is $\sim$ 120m Rials.

[7]This penalty was set at 20m Rials as of March 2018

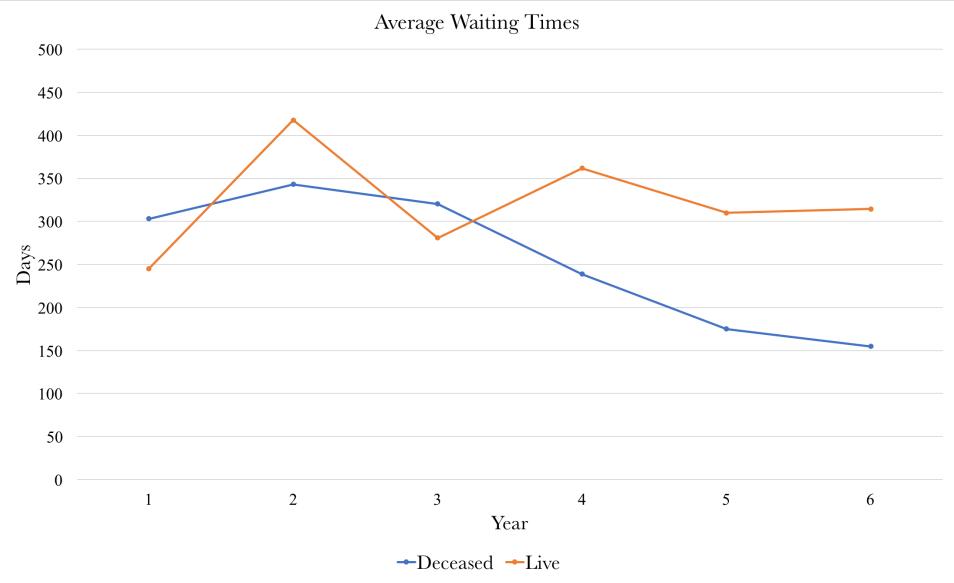


Figure 2: Average waiting time (in days) for deceased and live queues.

Finally, emotionally related donors will have access to immunosuppressive drugs through government and will receive the gift of altruism if they register in the Kidney Foundation. This gives them strong incentives to register at the foundation offices.

Data

We work with the anonymized data for every transplant in Tehran from the first quarter of 1391 to the last quarter of 1396. The data is provided by the kidney foundation of Iran. For each transplant, we observe patient's and donor's blood-type, age, gender, zip code, date of transplant, date of registration in the institute (for patients), and type of transplant (paid, emotionally related, or deceased donors). We do not observe patients who are currently in the queue or those who arrive and leave the queue without transplant.

We have access to data for years between 1391 to 1396 of the Iranian calendar (March 2012 to April 2017). To make notation simple, we will drop the first three digits of the year, so when we refer to year X of the data, what we mean is $139X$.

To estimate wealth, we use data from housing sales in Tehran. For each zip code, we take the average of the house price in that area as a proxy for wealth.

4 Market Outcomes

4.1 Waiting Times

Waiting time to receive a kidney transplant is a key performance measure of a kidney transplant system. In the United States, the median waiting time of patients to receive a kidney is more than 1300 days. In the Tehran market, once a physician concludes that transplant is the treatment of choice for her patient, she introduces the patient to the foundation. Therefore, we define waiting time to be the time between a patient's date of registration and date of transplant. Figure 2 shows the average waiting time of deceased and live kidney recipients. In the final three years of data, the average waiting time for live kidneys is nearly 320 days, while the average waiting time for deceased kidneys is about 260 days. This suggests that the kidney transplat system in Tehran is working well from a waiting time perspective.[8]

4.2 Supply and Crowd out Effect

Figure 3 shows the quantity of transplants in Tehran from deceased, live unrelated and live related donors. There are two important facts in this figure: First, the number of transplants involving live unrelated (paid) donors is close to the number of deceased donors, suggesting that compensating donors can indeed encourage kidney sales. In fact, our estimations show that the price elasticity of supply for kidney donors is 0.66. (See Appendix B for calculations.) The second important fact about supply is that the annual number of live related donors is always less than 10. There is, however, an important caveat here. We do not know the number of relative donors in the counterfactual world with no monetary market for kidneys; it could be that the number of relative donations was virtually zero even in that world. While this is logically possible, we think it is an unlikely hypothesis, since in the three years before the establishment of the monetary market (1985-1987), a total of 274 transplants were performed from living related donors (Ghods, 2002). This suggests that legalizing kidney sales has almost entirely crowded out altruistic donation.

4.3 Segregation by Wealth: Who Buys and Who Sells?

We use zip-code data of market participants to estimate their wealth distributions, as shown in Figure 4. This figure illustrates two important facts: First and foremost, those who sell their kidneys are on average poorer than those who receive deceased or live kidneys.

[8]It is worth noting that our measure of waiting time has some "mechanical" minimum: When a patient is at the top of the queue and can have transplant, she performs additional crossmatch tests to evaluate tissue-type compatibility. Since some blood-type compatible donors end up being tissue-type incompatible, this process can take at least a few weeks, and sometimes more. After finding the right donor, in some cases donors renege for various reasons. This also adds to waiting time.

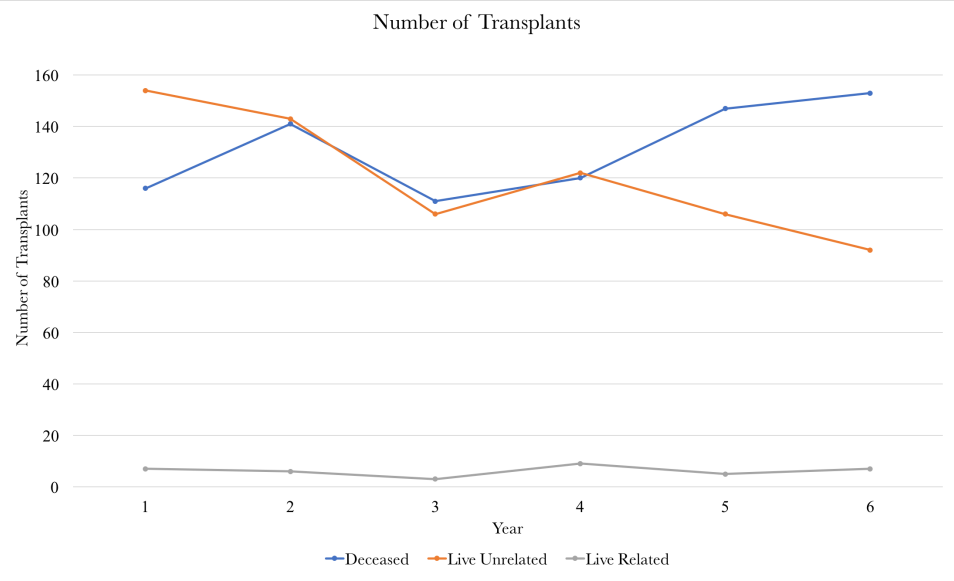


Figure 3: Number of transplants per year in Tehran, from year 1 to 6.

Moreover, those who donate their kidney in this market are among the poorer population in the society. Median of the wealth index used in this paper is 2360 Million Rials in the city of Tehran. In the donor population, 96% of donors come from families with lower wealth than this median. This percentage is 24% for patients who receive kidney from live donors, and 30% for those who receive kidney from deceased donors. This fact shows that kidney recipients from live donors are wealthier than recipients from deceased donors. To achieve a better understanding of the difference in wealth between donors and recipients of both kinds, we measure the difference between the empirical distributions of wealths.

Kolmogorov-Smirnov test is applied to test significance of difference between the empirical cumulative distributions. The results have shown that cumulative distribution function of recipient wealth is significantly higher than the one for donors (vertical distance between the two distributions is ? units with p-value equal to zero.), which means that more donors are in the range of lower wealth levels than recipients, while more recipients have higher wealth levels than donors. Kolmogorov-Smirnov test for comparing wealth levels between two types of recipients also shows that recipients from live donors are wealthier than recipients from deceased donors in the same sense. (vertical distance between the two distributions is 0.19 units with p-value equal to zero.)

A more precise comparison of the wealth in donors and recipients populations is possible by using the whole wealth distributions beside the above summary statistics. We use Kolmogorov-Smirnov test to verify and measure the dominance of the wealth distributions.

However, note that even those patients who do not participate in the monetary market directly benefit from the market, because the flow of patients who choose the monetary

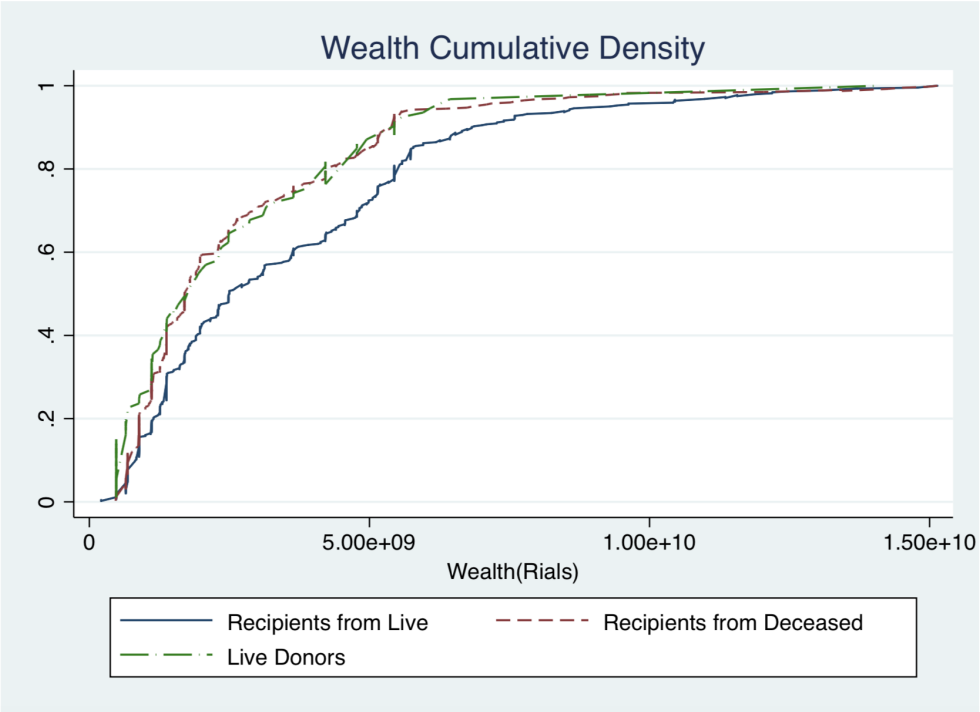


Figure 4: Commulative wealth distribution of live recipients (blue), deceased recipients (red), and donors (green).

market will not receive a deceased kidney, which in turn reduced the congestion of the deceased queue. Analysis of this congestion effect is the main subject of the next section.

5 A Queuing Model of the Market for Kidneys

In this section, we introduce a queuing model of the Iranian market for kidneys and analyze its stationary dynamics. The point here is not to claim that the Iranian market for kidneys is at steady-state, but to introduce a stylized framework that can help us think about some equilibrium dynamics of the market in a systematic way.

Let λ be the inflow arrival mass of (infinitesimal) patients to the system. Upon arrival, a patient has two actions: She can go to the *deceased* queue to receive a deceased kidney, or she can go the *live* queue to pay for a live kidney. After this (endogenous) choice, a fraction α of patients enter the live queue, and the rest of them enter the deceased queue. The parameter α, which we refer to as the *market demand for live kidneys*, depends on the utility maximization problem of the agents, which in turn depends on the regulated price of the kidney and waiting times in both queues, in manners to be described soon.[9]

[9]There are two critical assumptions in our model, both of which are founded on stylized facts: First, while agents can choose to go to both queues, such patients are rarely observed in data, thus we rule out such possibility. In addition, λ (total demand) is an exogenous parameter, whereas in reality if the price of

Let μ_d be the (exogenous) inflow arrival masses of (infinitesimal) deceased kidneys. Also, let $\mu_l(p)$ be the inflow arrival mass of (infinitesimal) live kidneys, where p is the regulated price of the kidney, $\mu_l(0) = 0$, and $\mu_l'(0) > 0$. We assume that matching is frictionless, so whenever a deceased or live kidney arrives, it is instantly matched to a (randomly chosen) patient in the corresponding queue. This means that, in the language of queueing theory, μ_d and $\mu_l(p)$ are *service rates* of the deceased and live queues, respectively. This simplifying assumption could be problematic if patients and donors were engaged in costly decentralized search, but given the centralized nature of the market and the fact that in status quo there are always some patients waiting in the queue, it is a reasonable approximation that gives us analytical tractability. The assumption of random matching (as opposed to first-come first-serve) is a harmless assumption to keep stationarity, since eventually what matters for a patient decision to join a queue is her expected waiting time before joining a queue.

We denote by L_d and L_l the stationary mass of patients waiting in the deceased and live queues, respectively. A patient who is in the queue departs according to some Poisson arrival of rate $\delta < 1$, so the departure outflow from queue $j \in \{d, l\}$ is simply δL_j. Let $m_j = \mu_j / L_j$ be the *matching rate* of queue j. An agent who is waiting in queue j will exit the queue either by getting matched (which happens at rate m_j) or if her departure time arrives (which happens at rate δ).

Let Q_j be the lifetime present value of a type $j \in \{d, l\}$ kidney for all patients, where $Q_l > Q_d$. We assume patients are homogeneous in how much they value kidneys.[10] Nevertheless, patients are heterogeneous in their wealth levels. We model the role of wealth in agents' decision in a reduced form fashion in the following way: Each agents has a type θ which is drawn independently from a distribution $f(\theta) \in (0, 1]$, where $f(\cdot)$ is a continuous and atomless distribution. If an agent of type θ purchases a kidney of type j at price p, her utility will be $Q_j - \theta p$. Using this formulation, θ is a way to think about the *marginal value of money* for a patient – the poorer a patient, the higher her marginal value for money.

Patients are risk-neutral and expected utility maximizers. Let $V_j(\theta, t)$ denote the value of entering queue j for an agent of type θ who enters the queue at time t. An agent of type θ who decides to enter queue j at time t will have the following value function equation in steady-state and dropping t:

$$V_j(\theta, t) = -e^{-(m_j+\delta+r)\Delta t} V_j(\theta, t + \Delta t) + (1 - e^{-m_j \Delta t})(Q_j - \theta p_j) + (1 - e^{-\delta \Delta t})0.$$

kidneys or waiting times are too high, patients can get kidneys from their emotionally related donors. Such donors are virtually nonexistence in our data, even for periods that waiting times or kidney price are high. We therefore take demand as fixed.

[10] This assumption could be relaxed by including an idiosyncratic shock to each agent's value for a kidney, but for our purposes, this only adds to expositional complexity. In addition, since our agents are heterogeneous in wealth, their "willingness to pay" for a kidney varies.

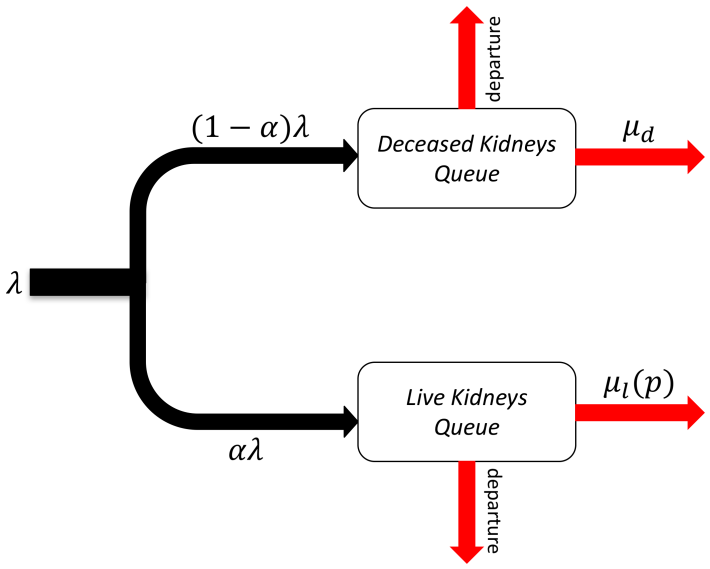


Figure 5: A flow diagram of the model.

Where $p_d = 0$ and $p_l = p$ is the regulated price of kidney. The first term on the right-hand side of the equation captures the waiting cost, the second term is the value function conditional on not getting matched in the interval $[t, t + \Delta t]$, the third term is the value of getting matched and paying price p_j and the last term is the rate of departure in $[t, t + \Delta t]$ interval which gives the patient a normalized utility of 0. Solving for the steady-state of the market, we will have:

$$V_j(\theta) = \frac{1}{m_j + \delta + r}\Big(m_j(Q_j - \theta p_j)\Big)$$

Let $V(\theta) = \max(V_l(\theta), V_d(\theta))$. In equilibrium, there is a cutoff type $\theta^* \in (0, 1]$ that is indifferent between the two queues, and all types $\theta > \theta^*$ will choose the deceased queue, while all types $\theta < \theta^*$ will choose the live queue. At equilibrium equilibrium, $\alpha = F(\theta^*)$. θ^* is the solution to:

$$\frac{1}{m_l + \delta + r}\Big(m_l(Q_l - \theta^* p)\Big) = \frac{1}{m_d + \delta + r}\Big(m_d Q_d\Big). \tag{1}$$

This equation shows that the market clears in (the exogenously regulated) price, as well as the waiting times (i.e., matching rates) of both queues.

The flow equations of the market at steady-state are:

$$\mu_d + \delta L_d = (1-\alpha)\lambda \tag{2}$$

$$\mu_l(p) + \delta L_l = \alpha\lambda \tag{3}$$

Equations (1), (2), and (3) characterize the steady-state of the market by pinning down $\mu_l(p), m_l$ and m_d. Note that $L_l = \mu_l/m_l$ and $L_d = \mu_d/m_d$, so pool sizes are also known given these variables. A simple calculation shows that the waiting time in a queue $j \in \{l, d\}$ is equal to $w_j = 1/(m_j + \delta)$. This discussion is summarized in the following propositions, which shows that for each value of p (which is the only policy tool of the model), the steady-state of the market is uniquely characterized, so long as we do not hit corner cases. The full proof is in the appendix.

PROPOSITION **1** *For a given regulated price p, $\mu_l(p), m_l(p), m_d(p)$ and $\alpha(p)$ are uniquely determined in a stationary system with positive L_l and L_d.*

5.1 Congestion Externality

We will now argue that in our framework, legalizing kidney sales makes *all* patients better off, including those who cannot afford to purchase a kidney. That said, wealthier patients benefit more from the market. We show this in a series of short arguments.

LEMMA **1** *$V_d(\theta)$, the value of entering the deceased queue, is minimized at $p = 0$ for all θ.*

Proof. By Little's law and Equation 5, $w_d = ((1-\alpha)\lambda - \mu_d)/(\delta(1-\alpha)\lambda)$. This shows that w_d is a decreasing function of α. When price is 0, there is no supply of live kidneys. Therefore, $m_l = 0$ and $w_l = \infty$ and so $\alpha = 0$, which means all patients choose the deceased queue. Hence, at $p = 0$, we have the *highest* possible waiting time for the deceased queue (since w_d is decreasing function of α). On the other hand, the value of entering the deceased queue is a non-increasing function of the waiting time in the deceased queue. So this value achieves it minimized at $p = 0$. ■

The next lemma shows that all patients are better off with a market for kidneys

PROPOSITION **2** *$V(\theta)$, the value of entering the market, is minimized at $p = 0$ for all θ.*

Proof. Recall that $V(\theta) = \max(V_l(\theta), V_d(\theta))$. When price is zero, $V(\theta) = V_d(\theta)$. Hence, by Lemma 1, $V(\theta)$ is minimized at $p = 0$. ■

These two lemmas show that the live market has a positive *congestion externality* on the deceased market. When there is no market, all patients join the deceased queue, and this is

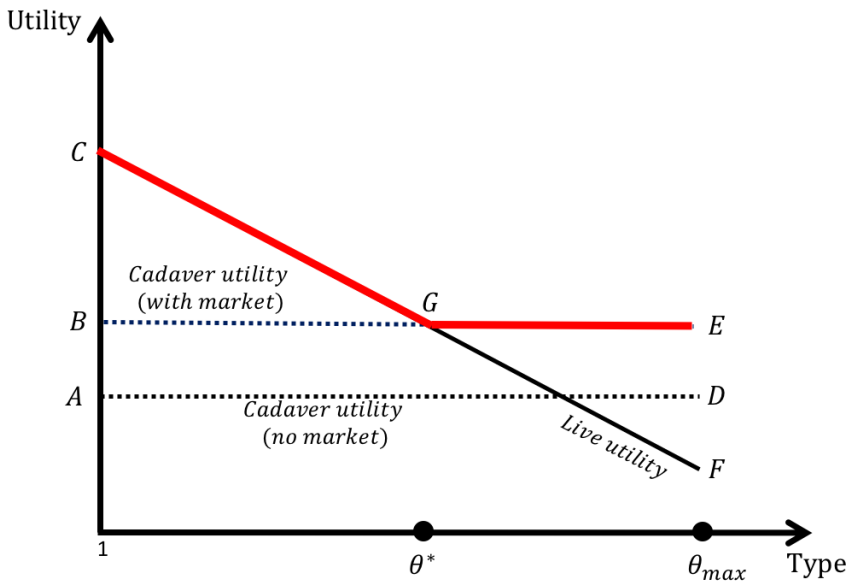


Figure 6: Congestion externality and the equality-efficiency trade-off of the kidney market. A monetary market for kidneys changes the utility curve of patients from (AD) to (CGE) (red thick line), so all types are better off, even though types with $\theta > \theta^*$ will not participate in the monetary market. Lower types (wealthier patients) benefit more from the market.

when the waiting time of the deceased queue is maximized. Setting the price of kidneys at some $p > 0$ can lead to one of the following two outcomes: (1) The new price is such that all patients still prefer to go to the deceased queue. In this case, effectively nothing changes. (2) The new price is such that some patients choose to join the live queue. Then average waiting time of the deceased queue *must* decrease (since its supply is fixed) so patients who choose the deceased queue are now better off. By revealed preference, those who join the live queue in equilibrium must bet better off as well.

We now turn into the inequality implications of the market for the patients. Recall that with no market for kidneys, all patients enter the same queue, so they are all treated equally. The existence of a market for kidneys makes patients who can afford to purchase a live kidney better off compared to those who cannot.

PROPOSITION **3** *Suppose* $0 < \alpha < 1$ *and let* θ^* *be the cutoff type. Then, for any* $1 \leq \theta_1 < \theta^*$ *and* $\theta_1 < \theta_2 \leq \theta_{max}$, $V(\theta_1) > V(\theta_2)$.

Proof. Let V_d be the utility (of all types) from the deceased queue. First consider a patient with $\theta_2 \geq \theta^*$, so the patient chooses the deceased queue. Then, consider a patient of type θ_1' such that $\theta_1 < \theta_1' < \theta^* - \epsilon$ for some arbitrarily small ϵ. This type chooses to purchase a kidney. By revealed preference, $V_l(\theta_1') \geq V_d$. Since $\theta_1 < \theta_1'$, it follows that $V_l(\theta_1) > V_d = V(\theta_2)$

Now consider a patient with $\theta_2 < \theta^*$. Both θ_1 and θ_2 choose purchase a live kidney in

this case. However, it is less costly for θ_1 to pay for kidney compared to θ_2, while they both face the same waiting time. Hence, $V(\theta_1) > V(\theta_2)$. ■

The intuition for this is clear: The deceased queue is an "outside option" for all patients. Without a market, all patients are equal. With market, those who join the live queue (wealthier patients), by revealed preference, must prefer the live queue to the deceased.

Figure 6 provides a simple framework. With no market for kidneys, all types of patients receive a fixed $V(\theta)$, which we show by line AD. With a market for kidneys with positive demand, waiting time for the deceased queue decreases, so the $V_d(\theta)$ equally increases for all θ (line BE). On the other hand, a patient's utility from the live queue is a decreasing function of her type (line CF) since it is more costly for poorer patients to pay for kidney. The cutoff type θ^* is exactly the type for which CF and BE lines intersect. Types higher than θ^* (poorer types) choose to join the deceased queue and types below θ^* (wealthier types) choose to join the live queue. Hence, the new $V(\theta)$ function is the CGE curve, which is strictly above the AD line for all types; that is, all types are strictly better off when there is a functioning kidney market.

5.2 A Simple Welfare Bound for Patients

Equation 1 offers a simple way to provide a lower-bound on welfare gains of legalizing kidney sales. Notice that all patients above the cutoff type receive a value $\frac{m_d Q_d}{m_d+\delta+r}$ and those below the cutoff type receive a value *higher* than that. Thus, $\frac{m_d Q_d}{m_d+\delta+r}$ is a lower-bound on welfare, which requires no information on details of the monetary market or distribution of θs.

In this equation, Q_d, δ and r are all exogenous variables. Establishing a market impacts this lower-bound only through m_d. If setting a $p > 0$ increases the matching rate of the deceased queue from m_d to m'_d, this would increase a patient's welfare by at least:

$$\frac{m'_d Q_d}{m'_d + \delta + r} - \frac{m_d Q_d}{m_d + \delta + r}$$

To get some intuition, suppose that the distribution of types is uniform. Then, the welfare gains of legalizing kidney sales at some price p is the area between AD line and CGE curve in Figure 6. A lower-bound for this area is the area of the rectangle $ADEB$. That is basically what we are calculating as the lower-bound on welfare gains.

We continue by estimating the parameters. We emphasize that this should be seen as a calibration exercise to provide some estimate for how large welfare gains can be, as opposed to a detailed structural estimation. The readers can put their own priors into this equation and come up with their own welfare lower-bound estimates.

The National Institute of Diabetes and Digestive and Kidney Diseases reports the one-year survival rate for dialysis patients to be around 80%, whereas the two-year, five-year, and

ten-year survival rates are around 64%, 33%, and 10%, respectively.[11]. Setting $\delta = 1/5$ in our model matches these survival rates relatively well.[12] A year under dialysis is estimated to provide patients with a quality adjusted lifetime (QALT) of 0.52 (compared to a full healthy year), while a year after transplant gives a QALT of 0.75 (Held et al., 2016). This implies that receiving a kidney today is 69.33% more desirable than a kidney next year. A discount rate of $r = 0.36$ reasonably matches this.

By Little's law, we can estimate m_d from waiting time. Since $w_d = 1/(m_d + \delta)$, we have that $m_d = 1/w_d - 0.2$, where w_d is measured in years. The waiting time in the deceased queue in Iran is around 0.83 years in the past two years, which translates into a matching rate of 1.004. Thus, in the presence of the market for live unrelated kidney, a patient's value from entering the market is at least $\frac{1.004Q_d}{1.564}$.

We proceed to calculate the lower-bound on welfare in two different ways:

1- Assumption on relative donation rate. In order to calculate the lower-bound on welfare, we need to calculate the counterfactual matching rate of the deceased queue in the absence of a regulated market. This requires knowing the number of altruistic donors in Tehran when kidney sales are illegal, which is challenging given that the kidney market has been legal for nearly 30 years. The simplest solution is to assume that the fraction of patients with an altruistic donor in Iran is no more than the U.S., which itself has one of the highest living donor per million populations rates of the world.[13] In 2017, for every 5 patients who entered the transplant waiting list, less than 1 of them had an altruistic donor. If the rate of altruistic donation in Iran is same as the U.S., then our model implies that the matching rate of the deceased queue in the absence of a market will be no more than 0.45. (See Appendix C for calculations.) Thus, without a market, the welfare of patients who do not have a relative donor is at most $\frac{0.22Q_d}{0.78}$. Hence, the welfare gains of legalizing kidney sales for each of these patients is:

$$\frac{1.004Q_d}{1.564} - \frac{0.22Q_d}{0.78} \simeq 0.35Q_d.$$

2- A revealed preference approach. We now employ a revealed preference approach to directly estimate a lower-bound on welfare gains. Let V_r be the value of receiving a kidney

[11]See `http://www.lkdn.org/dialysis_life_expectency/KidneyDialysisLifeExpectancy.pdf`, accessed 04/01/2018.

[12]The equivalent one-year, two-year, five-year, and ten-year survival rates under $\delta = 0.2$ of an exponential distribution will be 81%, 67%, 33%, and 13%, respectively.

[13]The rate of living donation in the U.S. is more than all the European countries, Canada, or Australia. For living donation rates in Europe, see `https://ec.europa.eu/health/sites/health/files/blood_tissues_organs/docs/ev_20141126_factsfigures_en.pdf`. For U.S., Canada, and Australia see `https://blood.ca/sites/default/files/ODT_Report_Highlights.pdf`

from a family or friend for all patients. The basic idea is simple: Receiving a kidney from a relative donor is an outside option for all patients. Thus, if there is a patient who chooses to join any of the live unrelated or the deceased queues, she must receive a utility at least as high as V_r. Therefore, if there is no relative donation, we can conclude that all patients are receiving a utility higher than V_r.

Applying this idea, we note that 1392 is the "worst" year in our data from a waiting time perspective. Yet, the number of relative donors is negligible. In this year, the average waiting time in the deceased queue is 0.94, which means that the value of entering the market is at least $V_d = \frac{0.86Q_d}{1.42}$. Since there are virtually no relative donors, V_r is at most $\frac{0.86Q_d}{1.42}$, or else we would have observed some relative donation in 1392. But this then means that in the counterfactual of banning kidney sales, if there is any relative donations, the waiting time of the deceased queue is necessarily more than 0.94. Thus, without a market, no patients' welfare is more than $\frac{0.86Q_d}{1.42}$. Thus, the increase in a patient's welfare from the market is at least:

$$\frac{1.004Q_d}{1.564} - \frac{0.86Q_d}{1.42} \simeq 0.04Q_d.$$

Notice that this new bound applies to *all* patients, unlike the previous bound which applied to only patients without a relative donor in the absence of the market.

The lack of reliable data on the value of statistical life in Tehran makes it hard to estimate Q_d in that context, but to get a sense of the value of Q_d in monetary terms, note that the medical literature recently estimated this value to be around $\$900,000$ in the U.S. (Held et al., 2016).

5.2.1 A counterfactual for the U.S.

We now provide a rough lower-bound on the potential welfare gains of a market for kidneys in the U.S., should the country adopt a successful market. In the current system, the average waiting time in the deceased queue is 3 years and 9 months, which translates to $m_d = 0.066$. Thus, a patient's value from entering the market is $\frac{0.066Q_d}{0.63}$.

For now, suppose that the U.S. kidney market can perform at least as well as the Tehran market; that is, there is some price at which the supply of living donors is enough to push the average waiting time of the deceased queue down to 0.83 years, similar to Tehran. This means that the matching rate of the deceased queue would be 1.004. Thus, for a patient who does not have a relative donor, the welfare gains from legalizing kidney sales is at least:

$$\frac{1.004Q_d}{1.564} - \frac{0.066Q_d}{0.63} \simeq 0.53Q_d.$$

The medical literature's estimate for Q_d is $\$900,000$. Using this estimate, establishing

a market increases the welfare of a patient with no relative donor by at least $\$483,000$. In 2017, nearly $29,000$ patients without a relative donor entered the transplantation waiting list. Thus, from this view, the lower-bound on welfare gains of establishing a market similar to that of Tehran in the U.S. is at least \$14 billion per year.[14]

The second welfare gains of legalizing kidney sales comes from the reduction in healthcare costs. A successful market for kidneys, on top of this, would decrease the average waiting time of patients by roughly 3 years. An early transplant of an American kidney patient saves the society around $\$250,000$ in the first five years. For the $29,000$ patients who entered the deceased queue in 2017 and had no relative donors, this would save the taxpayers another \$7.2 billion in healthcare spendings.

In the above calculations, we have implicitly assumed that there exists an equilibrium price at which the supply of live kidneys is enough to substantially reduce the average waiting time of the deceased queue. Recall that in 2017 the gap between demand for kidneys and supply of decreased donors is nearly $21,549$. Hence, the existence of a price at which the supply of living donors is $21,549$ is enough to guarantee any arbitrary low level of waiting time. This requires a relatively high price elasticity for living kidney donors. Becker and Elias (2007) estimate the equilibrium price of a kidney by calculating the additional income an individual will require to be indifferent between selling an organ or not, and predict that a price of $\$15,200$ is enough to have a large supply. In addition, they argue that because the size of the potential live donor market is huge relative to demand, the supply of kidneys is likely to be highly elastic. While a direct comparison between Iran and the U.S. is challenging, we note that the PPP equivalent of the price of kidney in Iran is nearly $\$10,000$ (in purchasing power parity), which is not too far from the estimate of Becker and Elias (2007).

6 Market Aversion

Our analysis so far shows that a kidney market can ease patients from suffering under dialysis, expand their lifetimes by several years, and reduce healthcare costs substantially. Despite these obvious gains, kidney sales are illegal is almost all countries of the world. Why?

There are several reasons to be wary of direct and indirect consequences of a market for kidneys. The opponents of a market are concerned that even a regulated market would come with costs to donors, to the vulnerable members of the society, and to the moral principles of the society in general. We now discuss some of those concerns in more detail and, whenever possible, we examine the validity of the arguments with our data.

[14]Note that legalizing kidney sales does not make patients with relative donors worse off. In calculating our lower-bound, we assumed their welfare gain is zero, which is a conservative assumption.



Figure 7: The percentage of transplanted patients who purchased a live kidney (as opposed to receiving a deceased kidney) for different wealth groups. While a regulated market increases the welfare of all patients, wealthier patients are more likely to receive live kidneys.

1- Cross-side inequality. Opponents of the market for kidneys are worried that the poor people are the likely sellers and rich people are the likely buyers. This is indeed the case in our data: 96% of paid donors come from households below the median income. This percentage is 24% for patients who purchase kidneys from live donors.

The idea of a world in which poor people sell their organs to the rich is certainly unsettling. Nevertheless, a defender of kidney markets could argue that poor people are already providing several services that the rich would not be willing to provide. Workers of risky jobs such as miners, construction workers, soldiers, or surrogate mothers are disproportionally from low-income households. Therefore, an argument merely based on the existing inequality between buyers and sellers cannot single out what is in a kidney market that makes us feel particularly disturbed.

2- Patient-side inequality. One concern about a kidney market is that it might *worsen* existing inequalities. Satz (2010) argues that a kidney market can expand inequality by including body organs in the scope of goods that money can buy. If poor patients cannot afford kidneys, then kidney market becomes a market for the wealthy. This concern is supported by our data. Figure 7 depicts, for each wealth decile, the percentage of patients who purchase live kidneys as opposed to deceased ones. The probability that a patient receives live kidney increases by wealth. Compared to the low 20% poorest patients, the top 20% wealthiest patients are nearly 2.5 times more likely to receive a live kidney.

A defender of kidney markets may respond to this concern in two ways: First, as we discussed in Section 5.1, even if wealthier patients are direct beneficiaries of the live market,

less wealthy patients indirectly benefit from it, since the live market reduces the waiting time of the the deceased queue.

In addition, this concern could theoretically be addressed by careful regulation. For instance, the law could allow purchases only by the government. Each living donor kidney would then go to the first patient on the waiting list similar to the way we allocate deceased donor kidneys today. This "government as monopsony" proposal assures that rich and poor patients have equal access to live kidneys.

2- Coercion. Several philosophers and ethicists argue that a market for organs can be coercive. For instance, Satz (2010), by referring to the study that in the Indian illegal markets 71% of sellers are married women (Goyal et al., 2002), argues that "given the weak position of women in Indian society, the voluntary nature of the sales is questionable."

On the particular concern of women coercion, we know that the numbers are substantially different in Iran: Nearly 85% of kidney sellers in Tehran are men. But it is challenging to empirically test whether the market is coercive, at least with our data.

Of course, the possibility that a market with voluntary participation could somehow coerce kidney sellers who behave according to revealed preference seems odd to an economist. Yet, it comes natural to some philosophers:

> *... market exchanges are not always as voluntary as market enthusiasts suggest. A peasant may agree to sell his kidney or cornea to feed his starving family, but his agreement may not really be voluntary. He may be unfairly coerced, in effect, by the necessities of his situation.* (Sandel, 2012, p. 123)

Selling a kidney due to "necessities of his situation" is by no means a hypothetical concern. In our conversations with donors in the Kidney Foundation, several of them mentioned loss of job or medical expenses as their primary reason to sell their kidneys. Our data confirms that most sellers are from poor households. As argued in a concurrent paper by Dworczak et al. (2018), the abundant of poor households with high marginal value for money can push the competitive equilibrium price down. Hence, a donor could end up selling a kidney not because he values his kidney less than other members of the society, but because he desperately needs money. Giving up a kidney at a low price due to high value for money can be interpreted as "coercion."

This particular interpretation of coercion can partially be addressed by redistributive market distortions. For instance, the regulated can set a high price floor to distort the split of the surplus. This would of course lead to rationing sellers, which decreases allocative inefficiency. But those sellers who sell are receiving a higher surplus. In fact, in Dworczak et al. (2018) claim that trading at such low equilibrium prices is not only morally questionable,

but also economically suboptimal, and setting high price floors in such environments can potentially improve welfare.

3- Crowding out intrinsic motivations. A primary concern with monetary payments is that they may not necessarily increase the supply of organs. The introduction of a kidney market can have two opposing effects on the supply: On the one hand, it can reduce supply by crowding out emotionally related donors. On the other hand, it can increase supply by incentivizing more people to sell their kidneys for cash. Which effect is more powerful? Our data shows that both effects exists. Relative donation is less than 4% of the market, while nearly 40% of transplants are facilitated through live paid donors. The elastic supply curve of living donors (~ 0.69) also suggests that a regulated market with the right price can increase supply of organs substantially, despite crowding out altruistic donations.

4- Information and incentives. Satz (2010) argues that kidney sellers may not know enough about harms and risks of donating kidneys, so we have the deal with the "agency" problem of donors. Ambuehl (2016) goes further and argues that financial incentives make people process information in a way that is more favorable to participation.

The *Kidney Foundation* in Tehran attempts to address this concern by informing potential donors about costs and risks of donation. In addition, donors go through mandatory mental health evaluation to assume they understand the risks, and they require a written permission letter from their spouse or their father as an additional step to address this concern. Whether these considerations are enough to claim that donors are making an "informed" decision is an open question.

5- Organ trafficking and the black market. Another concern regarding the kidney market is that it may provide a legal umbrella for organ trafficking. This is similar to the existing concern in the the legalized prostitution market, where some studies have argued that legalized prostitution can increase human trafficking (Cho et al., 2013).

There is limited data related to organ black markets in Tehran. That said, given the fact that a patient can receive a transplant quickly in the legal market, as well as the benefits that the government offers to patients in that market, we think there is little demand for black market transactions.

On the other hand, banning kidney sales has already created a large global black market for kidneys.[15] Clearly, donors are more likely to be exploited in such illegal markets. Thus, while one can safely claim that banning kidney sales decreases the number of individuals who

[15]New York Times reports that based on data of Organ Watch, an estimated $15,000$ to $20,000$ kidneys are illegally sold globally each year. See `https://www.nytimes.com/2012/06/29/world/europe/black-market-for-body-parts-spreads-in-europe.html`.

sell their kidneys for money, it does not solve the problem of organ trafficking – if anything, it can exacerbate it.

7 Concluding discussions

Our analysis of the Tehran monetary market for kidneys suggests that compensating donors has substantial welfare gains. It can increase supply of organs, which in turn would ease patients from suffering under dialysis, extent the quality-adjusted lifetime of ESRD patients by several years, and would save significant amounts of healthcare costs. This of course comes with a series of ethical concerns. Theoretically, a well-regulated market can address some of the market-aversion concerns. For instance, the regulation could make the government the only legal entity allowed to purchase kidneys from the potential donors. The government then allocates the acquired kidneys to patients in a system similar to that of the deceased organs. This would ensure that the demand for kidneys is independent of the wealth of the buyer. The government could also set price floors to prevent trades at low prices and provide donors with special medical care and insurance for the rest of their lives.

At the same time, our analysis should not be seen as an unequivocal endorsement for legalizing kidney sales. Many ethical concerns of compensating living donors are not amenable to regulatory interventions. For instance, some philosophers argue that "certain moral and civic goods are diminished or corrupted if bought and sold" (Sandel, 2012, p. 123). Such arguments cannot be met by a government monopsony or other kinds of regulations. Therefore, even a rough answer to the question of "should there be a market for kidneys" would require going into matters which are not economical, which is outside the scope of this paper.

References

Ambuehl, S. (2016): "An Offer You Can't Refuse? Incentives Change What We Believe," *Browser Download This Paper*.

Becker, G. S. and J. J. Elias (2007): "Introducing incentives in the market for live and cadaveric organ donations," *Journal of economic perspectives*, 21, 3–24.

Cho, S.-Y., A. Dreher, and E. Neumayer (2013): "Does legalized prostitution increase human trafficking?" *World Development*, 41, 67–82.

Dworczak, P., S. D. Kominers, and M. Akbarpour (2018): "Redistribution through Markets," *Available at SSRN: https://ssrn.com/abstract=3143887*.

Ghods, A. J. (2002): "Renal transplantation in Iran," *Nephrology Dialysis Transplantation*, 17, 222–228.

Ghods, A. J. and S. Savaj (2006): "Iranian model of paid and regulated living-unrelated kidney donation," *Clinical journal of the American Society of Nephrology*, 1, 1136–1145.

Goyal, M., R. L. Mehta, L. J. Schneiderman, and A. R. Sehgal (2002): "Economic and health consequences of selling a kidney in India," *Jama*, 288, 1589–1593.

Held, P. J., F. McCormick, A. Ojo, and J. P. Roberts (2016): "A cost-benefit analysis of government compensation of kidney donors," *American Journal of Transplantation*, 16, 877–885.

Nikzad, A., M. Akbarpour, M. A. Rees, and A. E. Roth (2017): "Financing transplants? costs of the poor: A dynamic model of global kidney exchange," Tech. rep., Stanford University Working Paper.

Rees, M., S. Paloyo, A. Roth, K. Krawiec, O. Ekwenna, C. Marsh, A. Wenig, and T. Dunn (2017): "Global kidney exchange: Financially incompatible pairs are not transplantable compatible pairs," *American Journal of Transplantation*.

Roth, A. E. (2015): *Who Gets Whatand Why: The New Economics of Matchmaking and Market Design*, Houghton Mifflin Harcourt.

Roth, A. E., T. Sönmez, and M. U. Ünver (2004): "Kidney exchange," *The Quarterly Journal of Economics*, 119, 457–488.

——— (2005): "Pairwise kidney exchange," *Journal of Economic theory*, 125, 151–188.

Sandel, M. J. (2012): *What money can't buy: the moral limits of markets*, Macmillan.

Satz, D. (2010): *Why some things should not be for sale: The moral limits of markets*, Oxford University Press.

A Proofs missing from the text

A.1 Proof of Proposition 1

In any mean-filed equilibrium, in which α and thus the matching rate in the two queues are taken as given by each agent, we have the following relation between the value functions and type parameter θ: V_l is strictly decreasing in θ and V_d is constant. So, we can argue that in

any mean-field equilibrium, and any type θ', agent with type θ' optimally chooses live queue in equilibrium, it should be that

$$V_l(\theta') \geq V_d$$

Then, agent $\theta' - d\theta$ for any positive $d\theta$ should also optimally choose the live queue, since

$$V_d \leq V_d(\theta') < V_d(\theta' - d\theta)$$

The same line of argument follows for the lower types of any agent who optimally chooses deceases queue in the equilibrium. Therefore, any mean-field equilibrium in this setting should have some cutoff point in the types, $\theta^* \in (0, 1]$ for which all higher types choose the deceased queue and lower types choose the live queue. Agent with this cutoff type is then indifferent between the two queues if θ^* is in the interior of the type space.

A.2 Proof of Lemma 1

As assessed in Proposition 1, in any equilibrium, there is some $\theta^* \in (0, 1]$ who is indifferent between joining the two queues. We have also shown that the share of agents who optimally choose live queue in equilibrium is equal to the share of agents with types lower than θ^*. So, in equilibrium, $\alpha = \theta^*$.

So, equilibrium condition from agent θ^*'s indifference implies the following equation.

$$\frac{m_l}{m_l + \delta + r}(Q_l - \alpha p) = \frac{m_d}{m_d + \delta + r} Q_d.$$

Which after dividing both sides by $m_d \times m_l$, can be rewritten as

$$(Q_l - \alpha p)(1 + \frac{\delta}{m_d} + \frac{r}{m_d}) = Q_d(1 + \frac{\delta}{m_l} + \frac{r}{m_l})$$

Stationarity conditions in the two queues with positive length are

$$\mu_d + \delta L_d = (1 - \alpha)\lambda \tag{4}$$

$$\mu_l(p) + \delta L_l = \alpha\lambda \tag{5}$$

Replacing $\frac{\delta}{m_l}$ from the matching rate equations, we get

$$(Q_l - \alpha p)(1 + (1 - \alpha)\frac{\lambda}{\mu_d} - 1 + \frac{r}{\delta}(1 - \alpha)\frac{\lambda}{\mu_d} - \frac{r}{\delta}) = Q_d(1 + \alpha\frac{\lambda}{\mu_l(p)} - 1 + \frac{r}{\delta}\alpha\frac{\lambda}{\mu_l(p)} - \frac{r}{\delta})$$

$$-(Q_l - p - Q_d)\frac{r}{\delta} + (Q_l - \alpha p)(1 + \frac{r}{\delta})(1 - \alpha)\frac{\lambda}{\mu_d} = Q_d(1 + \frac{r}{\delta})\alpha\frac{\lambda}{\mu_l(p)}$$

Equilibrium share of patients who join the live queue, α, then should satisfy the following equation:

$$\alpha(1+\frac{r}{\delta})\big[Q_d\frac{\lambda}{\mu_l(p)}+(Q_l-\alpha p)\frac{\lambda}{\mu_d}\big]=-(Q_l-\alpha p-Q_d)\frac{r}{\delta}+(Q_l-\alpha p)(1+\frac{r}{\delta})\frac{\lambda}{\mu_d}$$

Now we need to show that this polynomial equation has a unique solution for α.

B Price Elasticity of Supply

In the supply side, every single person in the population can potentially be a candidate for live kidney donation. We are not able to observe the whole population's characteristics. So, we are not able to run a logit regression for the supply side of the market. Instead, we can run regression to estimate an aggregate supply equation as follows

$$\log(N_t)=\gamma_0+\gamma_1\log(p_t)+\nu_t$$

To run this regression, we use quarterly data where N_t is the total number of live donations in quarter t, p_t is the real price of kidney in that quarter, and ν_t is the normally distributed error term. In the above regression equation, estimated of the coefficient γ_1 will give us the price elasticity of demand. Our estimate for the average price elasticity of demand is 0.66 with p-value 0.15.

C Counterfactual Calculations

We calculate two lower-bound counterfactual welfare analyses for Iran and US. The counterfactual for Iran is clearly non-existence of the market, while for the US, the counterfactual is presence of a market for live unrelated kidney, that we assume has the same matching rate as the one in Iran. The general idea of this counterfactual analyses is described earlier in the paper. Below, we discuss the technical details of calculating the lower-bound of counterfactual welfare.

Iran Calculations based on Tehran data. To calculate the number of such patients who get the lower-bound benefit from existence of the market, we need to have the inflow of patients demanding kidney transplant. This data is available for the US, but not for Iran. Since we do not have this data for Iran in our data, we need to back it up from the available information. For this purpose, we use the inflow equations as in Equation (5) , and we also exploit Little's law as discussed in the text.

The result is as follows

$$m_l = \frac{1}{w_l} - \delta$$

and

$$m_d = \frac{1}{w_d} - \delta$$

. Furthermore, we have that

$$\lambda = \frac{L_l}{w_l} + \frac{L_d}{w_d} = \frac{\mu_l}{1 - \delta w_l} + \frac{\mu_d}{1 - \delta w_d}$$

where w_j is the waiting time in waitlist j in years, and δ is the annual death rate among kidney patients. From the data in Figure 2, the average waiting time for live waitlist in Tehran is $w_l = 1.14$ years and for deceased waitlist, this number is $w_d = 0.83$ years.

If we replace $\delta = 0.2$ as assumed earlier in the paper, the above equations imply that in the presence of the market, matching rates in the live and deceased kidney queues are $m_l = 0.7$ and $m_d = 1.005$. Average number of donations per year are $\mu_l = 116$ and $\mu_d = 127$. So, we can easily calculate the pool sizes and λ. $L_l = 194$ and $L_d = 118$, and finally, $\lambda \simeq 306$.

We then need to know or estimate the number of patients who have a relative or altruistic donor. In the U.S., for every five patients, slightly less than one of them enters the market with a relative donor. However, we do not know this number in Iran, because of the presence of market in the past 30 years and the crowd-out effect of the market.

The first solution proposed for this problem is to assume the following upper-bound for the fraction of such patients: for Iran analyses, we assume that this population constitutes 4/5 of the whole patients in need for kidney. Fraction 0.2 for patients who are able to receive a kidney from relatives of altruistic donors is supposed to be the same in Iran as in the US. Given that U.S. has one of the highest relative donation rates in the world, this could be thought as a conservative upper-bound for Tehran.

If there was no market in Tehran, all patients should have either get kidney from a related or altruistic donor or enter the deceased queue if they did not have that option. The welfare for those who did not have the related/altruistic option would be at best [16] equal to $\frac{m'_d Q_d}{m'_d + \delta + r}$ where $m'_d = \mu_d / L'_d$ from the above calculations. If the deceased queue does not explode in this counterfactual, then we can calculate L'_d using the flow equation and calculate m'_d accordingly.

$$L'_d = \frac{\frac{4}{5}\lambda - \mu_d}{\delta} \quad \Rightarrow \quad m'_d = \frac{\delta \mu_d}{\frac{4}{5}\lambda - \mu_d}$$

[16] At best, because we are assuming that those with relative or altruistic donor would not enter the queue and this assumption would mitigate the congestion in the deceased queue.

Under the same parametric assumption that $\delta = 1/5$, m'_d is calculated to be 0.2, and the lower bound for the welfare gain is then

$$\frac{1.005Q_d}{1.565} - \frac{0.22Q_d}{0.78} \simeq 0.36Q_d.$$

This welfare improvement from presence of the market is gained for at least $\frac{4}{5} \times 306 = 244$ patients per year.

US calculations. Given the arrival rate of new patients (35, 587 in 2017) and the arrival rate of deceased kidneys (14038 in 2017), the total number of living donors required to achieve $m_d = 1.8$ is 17990 donors. This is assuming $\delta = 0.2$. Changing δ to smaller values does not change this number substantially.

Sensitivity analyses. So far, all the calculated counterfactual welfare improvements were under certain assumption on the parameters of the model, death rate, δ, discount rate r, and the proportion of patients who have relative or altruistic donors, let's call this fraction x. It is helpful to make sure that the calculated welfare gain is not very sensitive to the choice of parameters. For this purpose, we can use the general formula above before replacing the parameters values.

For given inflow of patients, λ, the welfare from joining the deceased queue when there is no market is at best equal to

$$w_d^{nm} = \frac{\frac{\delta\mu_d}{x\lambda - \mu_d}}{\frac{\delta\mu_d}{x\lambda - \mu_d} + \delta + r}$$

So, the welfare improvement from presence of a market with the same matching rate as in Tehran for each patient who do not have any relative or altruistic donor can be written as

$$Q_d[\frac{1.005}{1.005 + \delta + r} - \frac{\frac{\delta\mu_d}{x\lambda - \mu_d}}{\frac{\delta\mu_d}{x\lambda - \mu_d} + \delta + r}]$$

This upper-bound welfare expression is decreasing in x, the fraction of patients without relative donor. Therefore, the welfare gain from presence of the market is increasing in x. However, even if we assume this fraction to be as low as 0.5, the welfare gain for Iran from existence of market will be at least $0.04Q_d \simeq \$36,000$ per patient.

The welfare gain expression is also decreasing in δ. For death rates as high as $\delta = 0.6$ instead of the previous rate of 0.2, the welfare gain for Iran, for example, will be $0.107Q_d \simeq \$96,000$ per patient.