A Time-Series Analysis of U.S. Kidney Transplantation and the Waiting List: Donor Substitution Effects and "Dirty Altruism"

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Abstract

This paper provides an econometric analysis of the relationship between live and deceased (cadaveric) kidney donations for the United States for the period 1992:IV through 2006:II. Statistical analysis shows that increases in deceased donor transplants reduce future live donor grafts, controlling for both waiting list effects and exogenous trends. This result has important, and potentially dire, implications for efforts to reduce the organ shortage by increasing use of cadaver donors.

Keywords: Kidney Transplantations, Donor Substitution Effects, Dirty Altruism, Cointegration

JEL Specification: I18, I19

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1 Introduction

The medical miracles represented by organ transplantation and immune-suppression therapy have saved hundreds of thousands of lives over the last thirty years.[1] While many patients have enjoyed life-altering improvements in health and longevity, hundreds of thousands more have been unable to take advantage of these great achievements of science because of a chronic and worsening shortage of organs for transplantation. While numerous organs exhibit some degree of shortage, the case of kidneys is by far the most severe in the U.S. and abroad. Public funding of hemodialysis treatment for virtually all patients suffering from End-Stage Renal Disease (ESRD) in the U.S., Europe, and in most other high-income countries has allowed the waiting-lists for kidney transplants to grow year after year.[2] As of August, 2009, the official U.S. kidney waiting list, maintained by the Organ Procurement and Transplantation Network (OPTN), had reached about 81,000 patients, while an additional 2,200 were waiting for kidney-pancreas transplants.[3] These figures vastly understate the significance of the shortage, however: 6,238 patients were removed from the official list in 2008 due to reasons of death (4,558) or deteriorating health (1680). Beard, Jackson, and Kaserman (2008) estimate that cumulative deaths on the U.S. list alone, since 1982, will exceed deaths from the Hiroshima bomb of WWII by 2010.[4] Further, dialysis itself is incredibly expensive, running around $72,000 per year in direct care costs per patient, and over 300,000 patients are currently receiving dialysis therapy under the Medicare program in the U.S. Long-term dialysis care has numerous severe medical consequences, and dialysis reduces the patient's prospects for a successful transplant.[5]

[1] Extensive reviews of the U.S. experience are available in Kaserman and Barnett (2002) and Goodwin (2006).

[2] Most countries have national authorities that maintain the "official" waiting list statistics. In the U.S., OPTN does this task. Supernational organizations such as Eurotransplant and Scandiatransplant maintain waiting lists that combine different national populations. OECD health statistics include census counts of dialysis populations and kidney transplantation. Data on U.S. dialysis programs is compiled by the United States Renal Disease System (USRDS).

[3] There are many more kidney dialysis patients than there are patients on the kidney transplant waiting list. This is because admission to the waiting list requires a variety of medical and social criteria be met. However, the waiting list itself does reflect, to some extent, the severity of the shortage, although on medical grounds it clearly understates it.

[4] U.S. deaths on the list vastly understate deaths from the shortage due to sickness removals.

[5] Steinbuch (2009) provides a concise summary of the main negative consequences of dialysis.

The organ procurement systems of virtually all countries except Iran share a few common features which have resulted in the current severe shortage of organs.[6] First, almost all nations prohibit compensation for organ donors, whether those donors are living (as can be done in the case of kidneys, for example), or deceased ("cadaveric"), as is necessary for many organs such as hearts or intestines. Second, living donors of kidneys (who surpassed cadaver donors for the first time in the U.S. in 2001) are generally required to have a stable, long-term private relationship with the recipient, such as kinship. Donations "to the waiting list" are generally prohibited, or else made quite difficult, in an effort to avoid paid donation disguised as altruism. In contrast, donations from cadavers must be anonymous, and ordinarily the families of deceased donors are not allowed to designate the patient to receive any harvested organs. Neither living nor deceased donors, nor their families, can receive compensation (the National Organ Transplantation Act of 1984 in the U.S. makes any such deal a felony), and indeed there is some evidence that living donors are not even compensated for their costs, broadly speaking.[7]

Because of the huge costs of the shortage of kidneys, and the life-or-death nature of this problem, the evolution of the kidney transplant waiting list, and the complex roles played by living and deceased donors in this process, is of great public interest. In broad terms, the waiting list for renal grafts is composed of those individuals who are admitted to the list by transplant centers using both medical and non-medical criteria. Not all patients who suffer from ESRD are viable candidates for transplantation.[8] Kidneys for transplant are obtained from deceased donors who meet relatively strict medical criteria: such persons are ordinarily disease free adults under the age of 60, who suffer brain-death in a hospital setting that allows their vital functions to be maintained pending organ removal. Such removals require family consent, and that consent is often not given.[9] Alternately, living donation is feasible and relatively low-risk in the case of kidneys, although it is

[6] Iran pays living donors under a state-administered system, and it has no waiting list for kidneys. See Ghods (2002).

[7] See Reilly *et al.* (1997) and Clarke *et al.* (2006).

[8] Estimates vary, but perhaps about 40% of dialysis patients in the U.S. are, on purely medical grounds, viable candidates. This number exceeds the waiting list y a substantial amount. See Barnett and Kaserman (2002), Ch. 2, for a discussion of the demand and supply for transplants.

[9] In the U.S., the "conversion rate" hovers around 50%. See Matas (2004).

generally necessary for patients to find a willing and compatible donor from among their family and closest friends.[10] The waiting list is sometimes described as being primarily composed of persons waiting for a cadaveric organ from a stranger, since most patients needing kidney transplants are advised to try to find a willing living donor at their initial diagnosis.

Many programs, with varying but modest degrees of success, have been implemented over the years in an attempt to increase the numbers of transplants performed.[11] Because altruism plays a fundamental role in the current system, the motivations of potential organ donors, and their families, are topics of great public moment. Since the families of brain-dead potential donors cannot legally be offered compensation for donation, they must be persuaded by other, less tangible means. Similarly, potential living donors , when faced with the critical medical need of a relative or close acquaintance, must decide whether the nontrivial personal costs of living donation are outweighed by the benefits.[12] Because these decisions are, in principle, uninfluenced by money, they are likely to be impacted by considerations directly related to the prospects of the patients involved, the degree of the shortage, and the extent to which the potential donor decision-makers view the current system as honest and fair. This paper identifies two such effects, uses a rigorous time-series analysis to look for them, and confirms the existence of one, while raising doubts about the reality of the other.

Our goal here is to examine two potential phenomena, discussed by those in the transplant community, which are potentially extremely important for any effort at reform within the current altruistic paradigm. First, because living donor and deceased donor kidneys are fairly good (but not perfect) substitutes, the question naturally arises as to whether increases in the cadaveric supply will displace living donor organs and, if so, to what degree? This phenomenon is plausible for several reasons. Because a living donor must consider making a very profound sacrifice to provide

[10] See Matas (2004) for statistics on living donation. OPTN also publishes annual figures on the relationships between living donors and recipients. Around 98% of donors give to relatives, close friends, or do so indirectly through paired exchanges.

[11] Beard and Kaserman (2006) provide a list. These innovations include mandated request, public service advertising, donor cards, paired exchange systems, presumed consent laws, and so on.

[12] It is quite likely that many living donors face “nonmarket” incentives to donate, and payments made within the family setting are quite beyond the ability of the Law to regulate.

a loved one with a donor organ, the prospects of that patient receiving a cadaver organ from another source directly affect the net benefit of making a living donation. In general, one would expect less enthusiasm from living donors when cadaver donations are relatively more plentiful. Further, because the UNOS algorithm will always make transplant matches that are genetically very favorable (matching six of six antigens), any patient on the waiting list has a chance to receive a very good match from a cadaver at any time, although this probability is small. Finally, one may take the view, common in the medical community, that living donation is ethically inferior, from the social perspective, and should be regarded as "second-best" , as it involves the violation of a healthy body. Thus, many see living donation as a symptom of desperation: if there were sufficient deceased donor kidneys, we could reduce or perhaps eliminate reliance on living donors.

A second issue, only recently introduced into the literature on the organ shortage by German economist Rigmar Osterkamp, refers to the effects of living donations on the willingness of bereaved families to allow deceased donations.[13] In particular, numerous press reports in the U.S. and abroad have described illegal "kidney deals", in which living donors are recruited from poor countries and paid to masquerade as willing, altruistic relatives. The existence of such schemes, which is undeniable but of quite uncertain magnitude, is often believed to undermine the efforts of legitimate national organ procurement agencies. Families of potential deceased donors come to believe that they are asked to make a gift, while other donors are paid, often huge sums, to provide organs for favored, wealthy patients. Osterkamp termed the resulting negative effect on cadaveric donation "dirty altruism", and sought to identify the phenomenon in a panel data set of OECD countries, but without success.

In this paper, we analyze time series data for U.S. kidney transplantation activities and the kidney waiting list in an attempt to isolate and identify these two effects. We are particularly interested in the substitution effect between living and cadaver donor transplants, because the ex-

[13] Osterkamp (2006) introduces this concept, and relates it to the donor analysis of Barnett, Beard, and Kaserman (1993). Osterkamp remarks, "However, there seems to be a growing awareness in the medical community, at least in Germany, that living donation may have only a small or even adverse net effect on total donation." (Osterkamp, p.3, note 1)

istence of such effects would be quite important in any evaluation of the likelihood of relieving the shortage using increased numbers of cadaver donors. In particular, the Organ Donation Breakthrough Collaborative (ODBC), a recent effort aimed at increasing the success rate for obtaining deceased donor organs, presupposes that an additional deceased donor kidney transplant is simply a one unit net increase in the number of transplants performed.[14] However, if such an increase leads to a significant reduction in subsequent living donor transplant levels, the potential ability of the ODBC to reduce the shortage and save lives will be undermined. Similarly, the possible existence of dirty altruism could also present serious constraints on reform efforts, since the percentage of patients receiving living donor transplants has grown enormously throughout the world as the shortages have worsened in most countries. If increases in living donation reduce later cadaveric transplants, a vicious cycle arises which causes the entire transplant system to falter.

This paper is organized as follows. Section 2 provides a concise background description. Section 3 presents our econometric model and estimation results. A concluding section describes the import of the results for organ supply reform efforts, and suggests further issues.

2 Background: Kidney Procurement and Transplantation in the U.S.

About eighteen patients die each day in the U.S. as a direct result of the shortage of kidneys for transplantation.[15] Hundreds of thousands endure the extremely difficult regime of hemodialysis, spending typically 14-20 hours per week hooked up to dialysis machines, suffering the profound aftereffects of dialysis therapy, or remaining at home, unable to work due to high rates of hospitalization, depression, and suicide.[16] Over twenty billion dollars are spent by the U.S. federal

[14] This conclusion is implicit in the discussion, but this sentiment is more explicit in other, related discussions, such as Gjertson and Cecka (2000).

[15] This is probably a large underestimate since very sick persons are never even placed on the list. As mentioned earlier, though, there were about 6,238 removals from the U.S. Kidney list in 2008 dues to death or sickness. There were many more deaths of dialysis patients, but of course not all of those persons would be valid candidates for transplantation.

[16] A vivid description of the lives of dialysis patients is in Perez-Pena (2006).

authorities annually on direct payments for dialysis treatment, transplantation, and related activities (Health & Human Services, 2008). Numerous studies have shown that kidney transplant action is the best treatment for many patients with ESRD, and that such transplants are extremely cost-effective for public health budgets, often "paying for themselves" in as little as 9-18 months.[17] No one argues that a large increase in the rate of renal transplantation is undesirable: serious debate focuses solely on the best means of achieving this goal, and whether donor compensation should be used in the effort.

In the U.S., as in many other countries, the procurement of organs for transplantation is, legally speaking, a solely public function. In the U.S., the United Network for Organ Sharing (UNOS) operates the Organ Procurement and Transplantation Network (OPTN), created by Congress in the National Organ Transplant Act (NOTA) of 1984. Designated regional authorities- the Organ Procurement Organizations or OPOs- have monopoly rights to collect organs within their regions. UNOS operates as a central clearinghouse for organs, using a complicated algorithm to match donated organs with those seeking transplants and registered on the waiting lists. Unlike many European countries, OPOs and large transplant centers have at least some autonomy, and control admissions to the waiting lists at their facilities. In principle, though, organs are matched to patients primarily on medical criteria, although time on the waiting list is also considered in some cases. Any hospital wishing to perform transplants and receive Medicare or Medicaid funding must comply with the UNOS regulations.

Kidneys constitute far and away the primary solid organ transplanted. About 80% of all patients on the U.S. waiting lists are ESRD patients needing kidney graphs.[18] Kidneys are unique among organs transplanted for two primary reasons. First, living donation is possible, since people ordinarily have two kidneys, but fare fairly well with only one. Surgery to remove a healthy kidney is relatively safe.[19] Second, the dialyzer, a machine that mimics the function of the kidney, exists

[17] See Karlberg and Nyberg (2006) for a review.
[18] As of September, 2009, OPTN reported total waiting list of 103,247, or which 80,975 needed kidneys, 15,928 were waiting for livers, and the balance needed other organs or multiple organ transplants.
[19] See Ibrahim *et al.* (2009).

and allows ESRD patients to survive for years while awaiting transplant. In the cases of many other solid organs, such as hearts, livers, or lungs, patient survival expectations on the waiting lists are quite short, and therefore the waiting lists for those organs are only a fraction of that for kidneys. Thus, the shortage of kidneys can be regarded as the defining problem for organ transplantation policy.

Kidneys for transplant are obtained from both living donors and deceased donors. Originally, the primitive state of immune suppression therapy implied that all transplants had to come from closely related, living donors, such as twins. With the invention of cyclosporine, cadaver organs became useful, and transplants from deceased strangers began to occur regularly. Living donors, however, have remained a vital part of the transplant equation because of the severe shortages of deceased donor organs of the necessary quality.

Although poorly understood by many people, very few hospital deaths (generally perhaps 1% or less) occur in conditions that allow transplantation of solid organs. In general, the donor must be "brain-dead", a physiological state characterized by the cessation of higher brain activity. The donor must be generally healthy, free of infections, less than 60 years of age, and so on. As a result of these traditional requirements, most such donors are victims of suicide, car/motorcycle wrecks, or strokes. Persons dying of heart attacks, for example, are generally not good sources of organs, and fewer are used.[20] The respiration of the donor is maintained mechanically until the organs are removed. Thus, the deceased "looks alive", since he/she continues to breath and often shows a normal appearance to loved ones untrained in medicine. Unfortunately, these facts lead many families to refuse donation, even in the presence of a donor card, trained requesters, physician support, and the terrible need for organs. Around 50% of all standard criteria donor candidates' families refuse in the U.S., although the rate varies widely among hospitals.[21] Clearly, effort by

[20] The "best" donors are termed "standard criteria donors" (SCD's), while those donating after cardiac death (non-heart beating donors, or NHB's) or with other undesirable traits such as infection or advanced age (so-called "expanded criteria donors", or ECD's) are associated with poorer medical outcomes and higher rates of rejection and infection. Rudich *et al.* (2002) provide statistics on the consequences of using NHB donors. In 2005, the U.S. UNOS hospitals transplanted 5294 SCD kidneys, 2000 ECD organs, and 793 from NHB donors.

[21] Some hospitals have conversions rates around 10%, while others achieve rates over 80%. These variations are the basis for the ODBC program of sharing "best practices" among member hospitals. See Shafer *et al.* (2006).

hospital staff can affect the success of donation requests, and thus the numbers of deceased donor transplants. Such transplants are extremely challenging, as there are severe limits on the time that may pass between removal of an organ and its transplantation into the patient.

In contrast, donations from living donors are quite leisurely affairs. Surgery may be scheduled for the convenience of all involved. Transplant success rates are higher, ischemic time is extremely short, and the expected lifetime of the graft is greater, other things equal. Surgeons, from the purely technical viewpoint, always prefer living donor transplants. The problem, of course, is that, in contrast to a cadaver, the donor in the living case is a second patient, needing care, post-operative evaluation, and so on. Such a donor has rights, whereas a cadaver is, under most legal systems, a special form of property.[22]

Those persons making a living donation of a kidney are taking a highly significant and irreversible step. Although such donation is relatively riskless (statistics suggest a death rate of less than .05%), there are some consequences. First, surgical evaluation, recovery, and so on will take weeks to several months. The law is taken to prohibit compensation, even for such costs as these. General anesthesia is used. After surgery, the donor has only one kidney, which prohibits them from certain activities, such as joining the military, playing NCAA contact sports, buying certain forms of insurance, and so on.[23] Long-term follow-up studies of donors have thus far found no deleterious effects from donation, but some physicians express concerns. Finally, living donation requires a physician to remove a healthy organ from a healthy patient, which is not a treatment for any disease the patient has, and is sometimes claimed to be mutilation in violation of the Hippocratic Oath to "do no harm."

Properly speaking, kidney transplants of either type involve a combination of stochastic events, combined with choices by both patients and medical officials. Accidents provide deceased donor organs. Fortunate genetic matching makes living donation possible. Yet, combined with these

[22] The Common Law provides for the protection of cadavers from abuse and mutilation. For a legal treatment, see Goodwin (2006) and Steinbuch (2009).

[23] The system in Iran, where paid living donation is the rule, provides for insurance benefits and care for donors precisely due to these sorts of effects. See Ghods (2002).

events, we also observe conscious choices made by patients, families, medical staff, and various public officials. Given the "correct" stochastic events, donors (or their families) must make the next, necessary step and agree to the donation. Since payment to such persons is prohibited, their decision calculus is likely to include factors that, in a monetized system of procurement, would be much less noticeable. In the case of the families of deceased potential donors, the urgency of the need for organs (which can be communicated to them), and the degree to which they believe the organ procurement system is fair and humane, may well affect their decision. The efforts of doctors, although complicated by their financial interests, also presumably reflect such motives. The term "dirty altruism" has been coined to describe the effect that suspect living donations might have on the willingness of families to provide cadaveric organs. Sensational press accounts of the sale of kidneys by living donors, which have become a staple of the popular media as the shortage has worsened, publicize the facts that some living donors receive very large cash payments.

The problem facing the potential living donor is much more difficult. Such a person may well feel pressure from family members and friends, albeit perhaps of a nonmonetary sort. If a donor cares about the patient, then a relevant question would be, "if I do not donate, what is the likely fate of the patient?". The answer to this question depends primarily on the probability that a cadaver organ will become available for the transplant. That, in turn, depends on the numbers of cadaver transplants and the size of the waiting list.

Thus, we may describe two phenomena that may affect the evolution of the kidney waiting list and organ donations: the "substitution effect", and the "dirty altruism" effect. In the substitution case, if such does occur, one would expect to see a negative impact of cadaver transplants in one period with living donations in a later period, controlling for the contemporaneous "need" for transplants, as proxied by the waiting list. The size of this effect would also be quite important, since it would determine the degree to which increases in cadaver organs will translated into more total transplants over time.

For the "dirty altruism" effect, one envisions a link between living donations now, and cadaver donations/transplants later. If this hypothesis is valid, then we should see that living donations now negatively impact cadaver transplants later. Further, though, this link almost surely requires the connivance of the media at large, and that is quite difficult to measure. It appears, however, that the numbers of reports of black market type transplants in the media is rising since 2000.[24] The actual dynamics are likely to be complex, however, and the best we can do here is merely look for evidence of a linkage between living and deceased donor transplants, recognizing that such a link, if it exists at all, could be explained in other ways.

We look for these effects using data on the waiting list, and the numbers of transplants performed within the UNOS system in the U.S. The challenge, however, is evaluating these phenomena in a statistically credible way, and that is our purpose in the next section.

3 The Econometric Model

Let $\mathbf{y}_t = [l_t \quad c_{t-1} \quad w_{t-1}]'$ be a vector of difference stationary random variables where l_t, c_{t-1}, and w_{t-1} denote the number of live donor kidney transplants at time t, the number of deceased donor kidney transplants at time $t-1$, and the waiting list for kidney transplants at time $t-1$, respectively, measured in natural logarithms. It should be noted that we include c_{t-1} and w_{t-1} in $\mathbf{y}_t$ instead of c_t and w_t, assuming that the potential live donors make their decisions based on the observed information/data on the number of cadaveric donors and the waiting lists.[25]

Assume that there is a nonzero vector of real numbers $\gamma = [1 \quad -\beta']'$, where $\beta =[\beta_1 \quad \beta]'$, such that $\gamma'\mathbf{y}_t$ is stationary, that is, $\mathbf{y}_t$ is cointegrated with a (normalized) cointegrating vector γ. Then, the triangular representation (Phillips, 1991) of such a cointegrated vector process is,

$$l_t = \alpha + \beta_1 c_{t-1} + \beta_2 w_{t-1} + \varepsilon_t \tag{1}$$

$$\Delta \mathbf{x}_t = \delta + \mathbf{u}_t, \tag{2}$$

[24] Cherry (2005) provides some vivid examples.

[25] As a robustness check, we implemented a cointegrating regression/test with contemporaneous variables. We found slightly weaker substitution effects but the results were overall qualitatively similar to those of the baseline model. Further, as our data is quarterly (not annual), one period lags are nearly contemporaneous.

where $\Delta \mathbf{x}_t = [\Delta c_{t-1} \ \ \Delta w_{t-1}]'$ is a 2×1 vector of differenced variables, α denotes a constant, δ is a vector of constants (drifts), ε_t is zero-mean stationary for β_1 and β_2, and 2×1 vector $\mathbf{u}_t$ is zero-mean stationary. We assume that the cointegrating vector γ eliminates both the stochastic and deterministic trends, thus time trend is not included in the cointegrating regression (1).[26]

We also investigate the validity of the so-called "Dirty Altruism" model described as follows.

$$c_t = \mathbf{h}'\mathbf{d}_t + \beta_1 l_{t-1} + \beta_2 w_{t-1} + \varepsilon_t \tag{3}$$

$$\Delta \mathbf{x}_t = \delta + \mathbf{u}_t, \tag{4}$$

where $\Delta \mathbf{x}_t = [\Delta l_{t-1} \ \ \Delta w_{t-1}]'$ is a 2×1 vector of differenced variables, $\mathbf{d}_t = [1 \ \ t]'$ denotes a vector of deterministic terms including time trend, and $\mathbf{h}$ is the associated coefficients on the deterministic terms.[27]

The ordinary least squares (LS) estimator $\hat{\beta}_{LS}$ for the cointegrating regression (1) or (3) is super-consistent as $\hat{\beta}_{LS}$ converges to the true value at the rate of T (sample size) even when $\mathbf{x}_t$ is correlated with ε_t. However, the asymptotic distribution of $\hat{\beta}_{LS}$ is asymptotically biased and non-normal. Therefore, statistical inferences based on the usual LS standard errors are not reliable. Furthermore, the LS estimator is asymptotically inefficient. Fortunately, there is an array of alternative methods such as Johansen's (1988) Maximum Likelihood (ML) Estimation method, the Fully Modified Ordinary Least Squares (FMOLS) method by Phillips and Hansen (1990), the Canonical Cointegrating Regression (CCR) method by Park (1992), and the Dynamic Ordinary Least Squares (DOLS) estimator by Stock and Watson (1993), which have better asymptotic properties than the LS estimator.

Here, we employ Park's (1992) CCR method to estimate the cointegrating vector. The main idea of the CCR is to implement the LS estimation via transformed variables using the long-run

[26] This is the case when the deterministic cointegration restriction is satisfied. When the cointegrating vector eliminates the stochastic trend only, $\gamma'\mathbf{y}_t$ is trend stationary. See Ogaki and Park (1998) for details.

[27] With this specification, we obtained empirical evidence for stochastic cointegration only, that is, the cointegrating vector eliminates stochastic trend but not a deterministic trend. We therefore include a time trend to the cointegrating regression equation (3).

covariance matrix of $\eta_t = [\varepsilon_t \;\; \mathbf{u}_t]'$, so that the LS estimator is asymptotically efficient. The CCR is as efficient as the ML procedure of Johansen but is robust to distributional assumptions because it is a nonparametric method. The CCR is applicable to more general cases of cointegrating regression models than the FMOLS.[28] Finally, the DOLS is easy to implement but the results may be sensitive to the choice of numbers of leads and lags. Thus, we view the CCR as appropriate to this problem.

4 Empirical Results

Our data are comprised of quarterly reports of UNOS/OPTN for End-Stage Renal Disease (ESRD) patients admitted to the UNOS kidney transplant waiting list, and renal grafts performed in the US by centers reporting to UNOS. Observations span from 1992:IV to 2006:II. We noticed strong seasonality in l_t and c_t (see Figure 1), so we will implement our empirical analysis with both the raw data and the seasonally adjusted data.[29]

As a preliminary analysis, we implement a unit-root test for the level variables and differenced variables. We use the conventional Phillips-Perron t test statistics that acquires the long-run variance nonparametrically. We choose Andrew's (1991) quadratic spectral kernel with an automatic bandwidth selection method. Results are reported in Table 1. We find that most level variables seem nonstationary, while differenced variables are stationary. The tests accept the null of stationary for w_t and the null of trend stationary for c_t. These results, however, don't seem reliable, because alternative tests, such as the augmented Dickey-Fuller test and the DF-GLS test (Elliott *et al.*, 1996), accept the null of a unit-root for these variables. The test strongly rejects the null of a unit-root for all differenced variables. So, we conclude that all level variables are integrated of order one.

Next, we estimate the cointegrating vector, testing the null of cointegration at the same time, for our baseline model (1).[30] Park's (1990, 1992) $H(p, q)$ test accepts the null of deterministic

[28] For example, the FMOLS can not deal with stochastically cointegrated models with deterministic trend in the repressors.

[29] We use the Census X12 method for seasonal adjustment. The source of this seasonality is unknown.

[30] We use the quadratic spectral kernel with automatic bandwidth selection method to obtain the long-run variance

cointegration with p-values of 0.603 and 0.246 for the raw data and for the seasonally adjusted data, respectively.[31] It is desirable to test the null of cointegration instead of the null of no cointegration (e.g., Phillips-Ouliaris test), especially when one is interested in testing an economic model that implies cointegrating relations because one can then control the probability (size) of rejecting the model. The coefficient estimates for c_{t-1} are negative, as expected, and significant at the 5% significance level. The variable w_{t-1} has strong and significant positive effects on l_t.

Finally, we investigate the validity of the model (3). Unlike the results of our baseline model, the $H(p,q)$ test rejects the null of deterministic cointegration at the 5% significance level, while accepting the null of stochastic cointegration, which implies that the cointegrating vector removes the stochastic trend only. Therefore, we estimate the cointegrating vector with a time trend and an intercept. The substitution effect of l_{t-1} was present with the exception of the case of raw data with no time trend. However, w_{t-1} has a sign that cannot be theoretically justified when a time trend is included. Therefore, "Dirty Altruism" model does not have convincing empirical support.

5 Discussion and Conclusion

Evidence in favor of the "substitution" hypothesis is very strong, and the magnitude of the observed effect is sufficiently large to suggest an important role for this phenomenon in procurement reform efforts. Unfortunately, the apparent sizes of the effect vary between the model estimated using seasonally-adjusted data, and that using the raw data. In both cases, however, the effect is large enough to be significant for procurement reform efforts that are predicated on increasing cadaveric donation.

Using the unadjusted data, a 10% increase in cadaver transplants in one quarter leads, on average, to a drop of about 5% in next quarter living donor transplants. Converting these percentages to raw numbers using end of sample values for the numbers of grafts, we see that an increase of

matrix. We also use VAR prewhitening method as recommended by Andrews and Monahan (1992).

[31] The $H(p,q)$ test has asymptotic χ^2 distribution with $q-p$ degrees of freedom. The test statistic diverges to infinity under the alternative hypothesis. Therefore, the test is consistent.

around 320 kidney transplants from deceased donors in one quarter will, on average, lead to an eighty operation reduction in living donor transplants in the subsequent quarter. Thus, the expansion of cadaver operations is partially undermined by a later reduction in living donor grafts, the loss amounting to about 25% of the initial increase in organs. This is a considerable effect.

Circumstances appear even worse when the estimates obtained from seasonally adjusted data are used. In this case, the initial 10% increase in deceased donor operations results in a 13% decline in later live donor grafts, or around 210 operations. Thus, the initial increase in deceased donor kidneys or 320 organs produces only around 110 additional transplants, other things equal.[32] If this estimate is even remotely correct, there are strong reasons to conclude that procurement initiatives that target increased deceased donor organ supply are highly unlikely to produce results anywhere near their stated goals. Indeed, the pursuit of such approaches may be detrimental to patient populations, if their implementation slows adoption of alternative reforms that do not suffer from this profound defect.

In contrast, evidence in favor of the "dirty altruism" phenomenon is not so clear. A part of the difficulty lies with the different stochastic properties the model given by (3) exhibits. As mentioned earlier, we find evidence that the cointegrating vector for this process removes the stochastic trend only, which is ordinarily taken to mean one must estimate the relationship including a time trend variable (and a constant term). When we do so, we do find effects that are mostly consistent with the dirty altruism hypothesis: increases in living donations in one quarter reduce cadaver transplants in the next, although the magnitude of the effects is smaller than in the substitution case. For example, using the trended model and the unadjusted data, we find that a 10% increase in living donations in one quarter leads to a reduction in subsequent cadaver donations of about 2%. Using seasonally adjusted data, this effect is estimated to be about 4%. On the other hand, the results for the effects of changes in the waiting list are curious and suggest that caution be applied in forming conclusions. The waiting list either appears to reduce cadaveric donation, or else to have no significant effect. The first case is quite implausible, but the second is reasonable if one assumes

[32] We ignore the later effects arising from changes in the size of the waiting list.

that the decisions of donor families are largely unaffected by the size of the need for organs (since, perhaps, that need is so great that modest changes in need are irrelevant), and that physicians and medical staff do not adjust their efforts in response to waiting list movements. Accepting all of this, one can credibly claim that the data is consistent with the dirty altruism hypothesis. Unlike the case of the substitution conjecture, however, dirty altruism is a somewhat more nebulous concept, and it is unrealistic to expect that a time series analysis of the sort presented here will be a definitive test of it. However, our findings suggest at a minimum that further investigation, perhaps at the micro level, is warranted.

On balance, it is likely and plausible that the supplies of kidneys for transplantation are intertemporally related, and that these relationships are quite unlikely to be helpful to efforts to reduce the costs of the severe shortage of organs for transplant. Reform efforts in U.S. kidney procurement have historically been proposed and managed from within the medical community. The ODBC, and similar programs in Eurotransplant and elsewhere, are examples of this circumstance. One unfortunate consequence of this orientation is that such programs view an additional organ obtained at time t as representing one additional transplant on net. Yet, recruitment of donors, and the donation decision, are made within an environment of severe and ongoing shortage caused by a lack of any mechanism to provide material incentives to donors or their families. In such conditions, one should expect various non-market factors to affect organ procurement to a degree unimaginable in a normal market setting.

Thus, the finding of a relatively significant substitution effect is intuitive, though disturbing. This effect is clearly large enough to matter. The existence of this effect, if confirmed elsewhere, should become a topic for discussion in the ongoing debate on procurement reform. Any proposal that does not address this phenomenon is likely to fall far short of its advertized potential.

"Dirty altruism", however, remains primarily conjectural. It is probable that any aggregated time series analysis will be too crude to uncover this effect. One should perhaps turn to micro surveys of donor families to resolve this issue, and that task remains undone.

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Table 1. Unit Root Test Results for the Null of Nonstationarity

Raw Data	Z_t^c	$Z_t^{c,t}$
l_t	-1.702 (0.425)	-3.079 (0.122)
c_t	-2.421 (0.141)	-5.728 (0.000)
w_t	-6.413 (0.000)	-1.340 (0.867)
Δl_t	-7.332 (0.000)	-7.307 (0.000)
Δc_t	-8.968 (0.000)	-8.884 (0.000)
Δw_t	-5.988 (0.000)	-8.588 (0.000)
Seasonally Adjusted Data	Z_t^c	$Z_t^{c,t}$
l_t	-2.282 (0.181)	-0.144 (0.993)
c_t	-1.296 (0.625)	-3.993 (0.015)
w_t	-5.974 (0.000)	-1.198 (0.901)
Δl_t	-6.443 (0.000)	-7.000 (0.000)
Δc_t	-9.413 (0.000)	-9.316 (0.000)
Δw_t	-3.216 (0.025)	-4.812 (0.002)

Note: i) Z_t^c and $Z_t^{c,t}$ denote the Phillips-Perron t test statistics when an intercept and when an intercept and linear time trend are included, respectively. ii) p values are in parentheses. iii) Standard errors are corrected nonparametrically by the quadratic spectral kernel with automatic bandwidth selection. iv) All variables are measured in natural logarithms. v) Alternative unit root tests for c_{t-1} and w_{t-1} provided evidence in favor of nonstationarity overall.

Table 2. Canonical Cointegrating Regressions and Cointegration Test Results

Raw Data	Estimates
Constant	0.944 (1.227)
c_{t-1}	-0.513 (0.223)
w_{t-1}	0.953 (0.058)
$H(0,1)$	0.271 (0.603)
$H(1,2)$	0.047 (0.829)
$H(1,3)$	2.383 (0.304)

Seasonally Adjusted Data	Estimates
Constant	4.821 (1.308)
c_{t-1}	-1.368 (0.236)
w_{t-1}	1.212 (0.058)
$H(0,1)$	1.347 (0.246)
$H(1,2)$	0.275 (0.600)
$H(1,3)$	0.542 (0.763)

Note: i) Starndard errors for the CCR estimates and p values for the $H(p,q)$ test statistics are reported in parentheses. ii) $H(0,1)$ tests the null of deterministic cointegration while $H(1,q)$ tests the null of stochastic cointegration without the determinstic cointegration restriction. iii) The quadratic spectral kernel with automatic bandwidth selection was used to obtain the long-run variance matrix.

Table 3. Canonical Cointegrating Regressions and Cointegration Test Results: An Alternative Specification

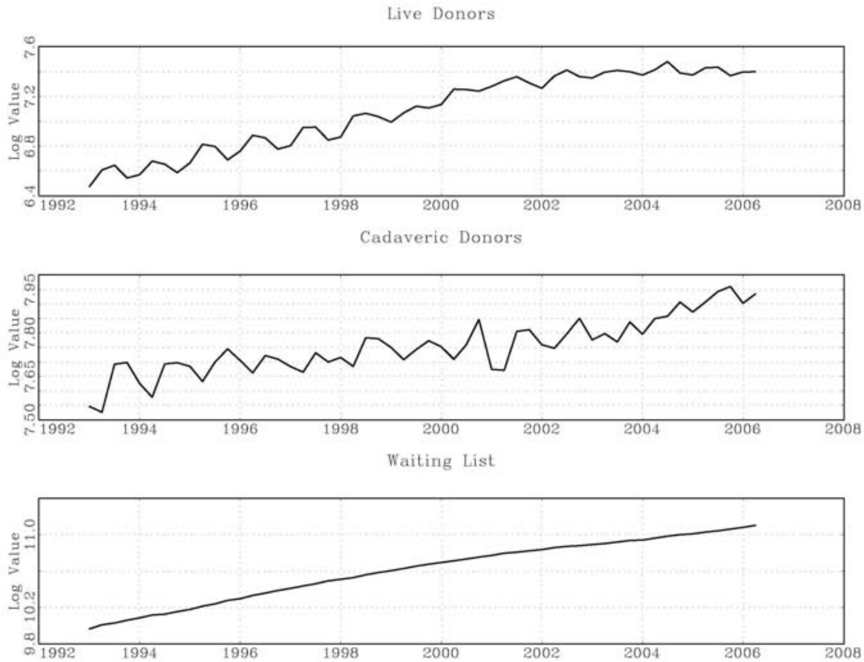
Raw Data	Estimates	Estimates
Constant	5.629 (0.703)	11.90 (1.169)
Trend	NA	0.016 (0.003)
l_{t-1}	0.033 (0.195)	-0.174 (0.085)
w_{t-1}	0.179 (0.190)	-0.312 (0.139)
$H(0,1)$	6.322 (0.012)	
$H(1,2)$	0.256 (0.613)	
$H(1,3)$	2.426 (0.297)	

Seasonally Adjusted Data	Estimates	Estimates
Constant	4.337 (0.686)	10.87 (0.923)
Trend	NA	0.015 (0.002)
l_{t-1}	-0.461 (0.192)	-0.437 (0.086)
w_{t-1}	0.629 (0.188)	-0.037 (0.125)
$H(0,1)$	7.620 (0.006)	
$H(1,2)$	0.423 (0.516)	
$H(1,3)$	0.955 (0.620)	

Note: i) Starndard errors for the CCR estimates and p values for the $H(p,q)$ test statistics are reported in parentheses. ii) $H(0,1)$ tests the null of deterministic cointegration while $H(1,q)$ tests the null of stochastic cointegration without the deterministic cointegration restriction. iii) The quadratic spectral kernel with automatic bandwidth selection was used to obtain the long-run variance matrix.

Figure 1. Kidney Transplant Data

(a) Raw Data



(b) Seasonally Adjusted Data