The Effect of Bundled Payments on Provider Behavior and Patient Outcomes*

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We consider how health care providers respond to bundled payments. Using detailed claims data from dialysis patients, we show that facilities' use of injectable anemia drugs fell nearly 50% following Medicare's transition from fee-for-service reimbursements to a bundle. We identify the causal effect of bundled payments on outcomes using a novel instrumental variable — patients at higher elevations naturally require lower doses of anemia drugs — and find that lower doses caused a decrease in mortality but an increase in blood transfusions. Overall, allocative efficiency increased as facilities cut doses the most for patients who benefit the least from the drug.

JEL Codes: D43, I11, L10

*We thank nephrologists Matthew Ellis and Ruediger Lehrich for providing valuable industry insights. We gratefully acknowledge research support provided by the Social Sciences Research Institute and the National Science Foundation (SES 1850736 and 1851615). We thank Jeffrey Hill, Alexander Marsh, Gabor Palinko, Lily Liu, Zilan Yang, Sungwoo Cho, and Hanmeng Wang for their research assistance. The data reported here have been supplied by the United States Renal Data System (USRDS). The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy or interpretation of the U.S. government.

1. Introduction

Health insurers use bundled payments to restrain reimbursement costs. Under a bundled payment system, providers receive a single reimbursement for an entire episode of care, with episodes typically defined as individual procedures like a joint replacement or chronic conditions like end stage renal disease (ESRD). Because bundled payments do not depend on the actual costs incurred during treatment, proponents of this system claim it encourages coordination among providers and reduces unnecessary expenses, virtues that have spurred Medicare's recent adoption of so-called alternative payment models for nearly 30% of its reimbursements (Shatto, 2016). Counteracting the possible advantages of bundled payments, however, is the incentive for providers to undertreat patients, as additional care does not yield any additional reimbursement. Given these inherent tradeoffs, we consider the precise ways in which providers reallocated resources in response to Medicare's adoption of a bundled payment system for dialysis, focusing specifically on how the reallocation affected patients' health and its implications for other parts of the U.S. health care system.

Before changing its payment model in 2011, Medicare reimbursed dialysis facilities with a hybrid system that gave providers a fixed payment for each dialysis session, a medical procedure that cleans the blood of patients with ESRD, and a fee-for-service payment for any injectable drugs administered during treatment. Most of these drugs were used to treat patients' anemia, a nearly ubiquitous condition among dialysis patients in which a lack of red blood cells reduces oxygen flow to the body's organs. The most common drug to treat anemia, epoetin alfa (EPO), was the largest prescription drug expenditure for Medicare prior to the bundle, totaling $2 billion in 2010 (U.S. Government Accountability Office, 2012). Administering EPO proved lucrative for providers, accounting for as much as 25% of revenue for the largest dialysis chain, DaVita, and up to 40% of its profits (DaVita, 2005). Many patient advocates raised concerns about the pervasive use of EPO, however, as excessive doses increase the risk of mortality and cardiovascular events (Besarab et al., 1998; Singh et al., 2006; Brookhart et al., 2010).

Partly as a result of unconstrained EPO reimbursements, Medicare's spending on the nation's 430,000 dialysis patients increased from $5 billion in 1990 to $33 billion in 2010, peaking at 7% of Medicare's overall budget. In response to these escalating costs, legislation enacted in 2008 set in motion an eventual payment reform for Medicare's ESRD program, split into two parts. First, in 2011, Medicare began bundling payments for anemia drugs with payments for dialysis treatments under the

new ESRD Prospective Payment System (herein referred to as the "bundle" or "PPS"). Second, to address concerns that the financial incentives from the bundle might harm patients if providers cut essential treatments to protect their profits, Medicare implemented the Quality Incentive Program (QIP) in 2012, which directly links payments to patient outcomes by allowing Medicare to reduce payments to facilities that fall below certain quality thresholds.

The move to bundled payments corresponded to a 48% drop in the average EPO dose given to patients each month from its peak during the fee-for-service era. Given that Medicare simultaneously imposed the bundle on all providers, however, we cannot immediately link the change in EPO doses to the change in reimbursements, as other contemporaneous changes could have coincided with the payment reform. And, although lower EPO doses reflect an unambiguous decline in the amount of resources used for dialysis treatments, the implications for patient welfare are less clear-cut: lower doses benefit those patients who were being overtreated prior to the reform but harm those whose anemia is now undertreated. Further complicating our attempts to measure the impact of the new reimbursement scheme, providers base their treatment decisions in part on a patient's underlying health, so any correlation between drug doses and outcomes may be biased by unobserved confounds. Reflecting this possibility, we show that OLS regressions of hemoglobin and blood transfusions on patients' EPO doses produce spurious negative and positive correlations, respectively, even though randomized controlled trials have shown that the drug in fact causes the opposite clinical response for these measures of anemia.

To overcome the empirical challenges stemming from coincidental changes in dialysis care and patients' unobserved health conditions, we use a novel source of exogenous variation in providers' treatment decisions to estimate the causal effect of bundled payments on EPO doses and outcomes: patients at higher elevations have higher baseline hemoglobin levels and are more responsive to EPO (Winkelmayer et al., 2009; Brookhart et al., 2011). When providers received fee-for-service reimbursements for injectable drugs, this physiological distinction made patients at higher elevations less profitable for dialysis facilities, as clinical guidelines recommend that they receive smaller doses of EPO, and hence facilities received correspondingly lower fee-for-service reimbursements. After the switch to bundled payments, the financial incentives flipped, with patients at higher elevations becoming inherently more lucrative for providers, because they naturally require smaller doses of EPO.

Although promising as a source of exogenous variation, elevation likely would not be a valid instrument on its own: just as elevation directly affects hemoglobin levels, it may also directly affect other

health outcomes. In light of this, we use the interaction between elevation and the payment reform as an excluded instrument while controlling directly for time trends and elevation in our first- and second-stage regressions. Our empirical strategy of interacting one variable with time-series variation and another with cross-sectional variation was first introduced by Card (1995) for measuring the returns to education and used more recently, for example, by Nunn and Qian (2014) to study the effect of U.S. food aid on conflict in recipient countries and Bettinger et al. (2017) to study the effect of online college courses on student outcomes. By instrumenting for EPO doses with the interaction term, our empirical strategy resembles a differences-in-differences estimation, with the first stage comparing EPO doses at facilities that typically use less of the drug due to their high elevation with those at lower elevations that typically use more of it, during the fee-for-service era when financial incentives favored higher doses relative to the bundle era when the financial incentives reversed. For this specification to have a causal interpretation, the interaction between a facility's elevation and Medicare's payment policy must only affect health outcomes through its influence on EPO doses, conditional on other controls, and several pieces of evidence suggest that our empirical strategy satisfies this requirement, including parallel pre-trends for patients' EPO doses across high and low elevations.

Using our instrumental variables, we find that the average post-bundle drop in EPO of 31.5% caused hemoglobin levels to fall by 3.4% and the number of blood transfusions to increase by 41.3%, suggesting worse management of patients' anemia. Part of the initial rise in transfusions reflects the profits at stake, as transfusions shift the costs of treating anemia from the dialysis facility (in the form of EPO) back to Medicare, given the reimbursement policies at the time that did not yet penalize providers for excessive transfusions.[1] For more acute outcomes, the decline in EPO caused hospitalizations from cardiac events to fall 11.6% and mortality rates to fall 14.1%.

Establishing the causal effect of EPO on health outcomes allows us to extend our analysis to evaluate the bundle's effect on allocative efficiency, a key contribution to the literature on alternative payment models. Because bundled payments make each dose of EPO a marginal cost rather than a marginal profit, facilities faced a financial incentive to use less of the drug compared to when they received fee-for-service reimbursements. We find that, while facilities did use less EPO overall, the cuts were not applied uniformly across all patients: the doses of patients who benefit the most from EPO fell 27.9%,

[1]To isolate the effects of the payment reform from other related changes, we restrict our sample to 2009-2012 in this paper, which is before the QIP had a meaningful impact on dialysis facilities. We evaluate the QIP directly in Eliason et al. (2020).

whereas those who benefit the least fell 35.4%. With the decrease in EPO concentrated among patients who received the smallest benefit from the drug, allocative efficiency increased as a result of bundled payments, in the sense that health outcomes *improved* while overall Medicare spending *declined* for those patients whose EPO doses were cut the most. The large for-profit dialysis chains accounted for the bulk of this reallocation.

Our results contribute to a recent literature examining the effects of Medicare's Bundled Payments for Care Improvement Initiative. Starting in 2011, this initiative sought to restrain health care costs by paying providers a bundled rate rather than a traditional fee-for-service reimbursement. Using observational data, Maughan et al. (2019) find that hospitals participating in the bundled payment initiative had worse outcomes for average patients than similar non-participating hospitals did, but not for the most vulnerable patients. Martin et al. (2018) document similar findings for lumbar fusion, where patients treated at participating hospitals had higher readmission and repeat surgery rates than patients at similar hospitals. By contrast, both Dummit et al. (2016) and Navathe et al. (2017) document lower costs for lower extremity joint replacements, with no meaningful difference in quality at participating hospitals. The findings from these studies may be biased, however, as the hospitals that selectively opt into bundled payments may have been particularly well suited to achieve savings, as discussed in Einav et al. (2020). Because our research design allows us to estimate causal effects, we contribute to the existing literature that has mostly used observational data from a small number of hospitals that voluntarily participated in bundled payments to show that such payment reforms produce large savings with little corresponding change in health outcomes.

One important exception to the observational studies of bundled payments is Finkelstein et al. (2018), who consider a randomized trial of a bundled payment model for lower extremity joint replacements. They find that patients treated at participating hospitals were less likely to be discharged to post-acute care, yielding a lower total cost of care with no differences in readmission or ER outcomes. Following this initial study, Einav et al. (2020) show that the bundled payment program, which was originally implemented as a 5-year randomized trial with mandatory participation by hospitals assigned to the new payment model but then unexpectedly made voluntary for half of these hospitals, is more likely to be adopted by hospitals that can increase revenue without changing behavior and for hospitals that had large changes in behavior during the mandatory participation period. They find that the voluntary regime generates inefficient transfers to hospitals and reduces social welfare compared to the

status quo, but that alternative designs could substantially reduce these inefficient transfers. We complement these results by evaluating outcomes for a chronic condition that extends beyond the first year of bundled payments, considering the effects on total Medicare spending among all patients, exploring heterogeneity across types of patients and providers (e.g., chain vs. independent), and assessing several relevant clinical measures (e.g., hemoglobin levels and infection rates).

Our work also connects directly to the large literature studying the effects of alternative payment models, including bundled payment systems. Many of these papers focus on Medicare's move in 1983 from cost-based reimbursements to the diagnoses related group (DRG) system for hospitals and its subsequent refinements (e.g., Cutler, 1995; Acemoglu and Finkelstein, 2008; Sloan et al., 1988a,b; Dafny, 2005; Eliason et al., 2018; Einav et al., 2018). In dialysis, the switch to a prospective payment system has also been studied extensively. For example, Chertow et al. (2016) document an abrupt decline in EPO doses beginning in late 2010 and look at related patient outcomes, finding that all-cause mortality, cardiovascular mortality, and myocardial infarction did not change significantly after 2012, while Hirth et al. (2014) find an uptick in blood transfusions following the start of PPS. In addition, our paper is among the first to examine how regulations that restructure Medicare's drug reimbursements affect allocative efficiency, particularly for Medicare Part B, which paid $26 billion for drugs on a fee-for-service basis in 2015 (MEDPAC, 2017).

Finally, our paper contributes to a recent literature specifically focused on the economics of the dialysis industry (e.g., Eliason et al., 2020; Dai, 2014; Cutler et al., 2017; Dai and Tang, 2015; Grieco and McDevitt, 2017; Eliason, 2019; Wilson, 2016a,b). Of particular relevance, Gaynor et al. (2018) study how dialysis providers balance patient health with financial incentives for EPO using a structural model of dosing decisions. Their findings suggest that, as expected, the traditional fee-for-service payment structure resulted in excessive doses of EPO. In their counterfactual simulations, doses would be 30–40% lower under the optimal linear contract.

Our paper proceeds with Section 2, which discusses the institutional details of the dialysis industry in the United States and describes the data used in our study. Section 3 presents findings from a preliminary time-series analysis of the effects of the policy reform. Section 4 presents results from our instrumental variable estimation of the causal effects of bundled payments. Section 5 then shows how the bundle affected allocative efficiency across patients and chains. Section 6 concludes.

2. Background and Data

2.1. Medical Background on Kidney Failure

The kidneys filter wastes and toxins out of the blood and produce erythropoietin, a hormone that stimulates red blood cell production. For patients experiencing chronic kidney failure, however, the kidneys no longer adequately perform these functions. To survive, those with ESRD must either receive a kidney transplant or undergo dialysis, a medical treatment that mechanically filters wastes and toxins from a patient's blood.

Those with ESRD can receive one of two types of dialysis, hemodialysis or peritoneal dialysis. Hemodialysis uses a machine (also referred to as a station) to circulate blood through a filter outside the body, which can occur at the patient's home or at a dialysis center, whereas peritoneal dialysis uses the lining of the patient's abdomen to filter blood inside the body.[2] Because over 90% of dialysis patients choose in-center hemodialysis, we focus on that modality for our analysis.[3]

2.2. Medical Background on Anemia

Anemia results from a lack of red blood cells or dysfunctional red blood cells in the body, which leads to reduced oxygen flow to the body's organs. Two blood chemical tests can be used to diagnose anemia and assess its severity: hematocrit and hemoglobin concentration. Hematocrit measures the volume of red blood cells as a percent of total blood volume, whereas hemoglobin concentration measures the amount of hemoglobin, a protein contained in red blood cells, in terms of grams per deciliter of blood (g/dL). The two measures are nearly isomorphic, with hematocrit approximately equal to three times the measured hemoglobin levels (Bain et al., 2017). In this paper, we focus on hemoglobin levels.

According to accepted guidelines, anemia is defined as hemoglobin below 14 g/dL for men and 12 g/dL for women. Common symptoms relate to a patient's quality of life, including fatigue, weakness, headaches, difficulty concentrating, a rapid heart beat, and insomnia, and in some cases anemia can contribute to a greater risk of serious heart conditions, hospitalization, and death (Kliger et al., 2013).

Nearly all patients with kidney failure suffer from anemia. As mentioned previously, healthy kidneys

[2]For more information, please see `https://www.niddk.nih.gov`.

[3]Please see Wang et al. (2018) for a discussion of the trends in dialysis modalities.

produce erythropoietin, which stimulates the production of red blood cells in the bone marrow. Patients with kidney failure have much lower levels of naturally occurring erythorpoietin, which is why those on dialysis are often anemic (Babitt and Lin, 2006). Among these patients, anemia is typically managed using a cocktail of drugs, with acute instances requiring blood transfusions.

2.3. Treatment of Anemia

Chief among the drugs used to treat anemia in dialysis patients is recombinant human erythropoeitin or epoetin alfa, the biologic commonly known as EPO. Manufactured by Amgen under the brand name EPOGEN®, EPO was approved by the Food and Drug Administration for the treatment of anemia in dialysis patients in 1989 (Kalantar-Zadeh, 2017), and since then has been a standard of care for the condition, with anemic patients treated with EPO requiring fewer blood transfusions and reporting improved appetite, activity level, and sense of well-being (Eschbach et al., 1987; Valderrabano, 2000). By 2005, 99% of in-center hemodialysis patients regularly received EPO, and in some years it represented the largest share of drug spending in Medicare's budget (U.S. Government Accountability Office, 2012).

By the mid-2000s, evidence from randomized controlled trials suggested that EPO may harm certain types of patients. In one study, Besarab et al. (1998) found that ESRD patients with congestive heart failure treated with EPO to achieve normal or high hematocrit levels had a higher probability of death and myocardial infarction. Similarly, Singh et al. (2006) found an increased risk of death and cardiovascular events among ESRD patients treated with EPO to normal or high hematocrit levels. Although these randomized controlled trials focused on specific patient populations, they raised concerns about the use of EPO more generally, and, in March 2007, the FDA issued a public health advisory for EPO, mandating a black box warning and advising physicians to adjust doses to target hemoglobin levels between 10 to 12 g/dL (Thamer et al., 2013). Over this time period, observational studies suggested similar adverse effects[4], although providers did not alter their doses much in response (Thamer et al., 2013). At the end of June 2011, the FDA amended the original black box warning, instructing providers to use a dose no higher than what is necessary to avoid blood transfusions.

[4]Please see Zhang et al. (2004), Bradbury et al. (2009), and Brookhart et al. (2010), among others.

2.4. Elevation and EPO

ESRD patients do not respond uniformly to EPO, with the elevation at which a patient resides providing one source of variation. At higher elevations, the richness of oxygen in the blood decreases, activating hypoxia-inducible transcription factors (HIFs). For patients with healthy kidneys, HIFs trigger an increase in natural erythropoietin and increased availability of iron in the blood stream, with bone marrow stimulated by the erythropoietin to use available iron to produce red blood cells. In ESRD patients, a higher elevation is associated with increased iron availability but little increase in erythropoietin, because their kidneys do not function properly. The increased availability of iron makes erythropoietin, whether naturally or artificially occurring, more productive. Consequently, patients at higher elevation tend to have higher baseline HGB levels and to be more responsive to EPO.[5]

Several medical studies have documented this phenomenon. Brookhart et al. (2008), for instance, show that patients living above 6000 feet receive 19% less EPO compared to patients at sea level, while Brookhart et al. (2011) find that patients moving from low to high elevations exhibit large and persistent increases in hematocrit and decreases in EPO doses relative to a control group. Moreover, Sibbel et al. (2017) find that even in 2012, after the 2011 payment reform, patients at higher elevations were less likely to receive EPO or intravenous iron, had higher mean hemoglobin levels, and had lower mortality rates compared to patients at lower elevations.

2.5. The Market for Dialysis

Dialysis patients choose their provider much like they do in other segments of the U.S. health care system, with those covered under Medicare able to receive treatment at any facility that has an opening. Patients primarily receive dialysis at one of the more than 6,000 dedicated dialysis facilities across the country, where they typically go three times per week for treatment that lasts three to four hours each visit. These facilities are run by a mix of for-profit and non-profit firms, with the two largest for-profit chains, DaVita and Fresenius, controlling over 60% of facilities and earning 90% of the industry's revenue (United States Renal Data System, 2014; Baker, 2019), and independent facilities comprising most of the remainder.

[5]Please see Winkelmayer et al. (2009) and Brookhart et al. (2011) for a more complete discussion of these physiological relationships.

Dialysis chains potentially have a number of advantages over independent facilities. Large chains, for example, may have lower average costs due to volume discounts for injectable drugs like EPO as well as centralized clinical laboratories; they may have a stronger bargaining position with commercial insurance companies (Pozniak et al., 2010); and their national brands and networks may make them more attractive to patients.

Chains also stand apart from independent facilities by having firm-wide standards that they implement across their facilities. Notably, large chains have operation manuals that dictate each of their facilities' procedures during treatment. Chains' system-wide standards may not universally lead to higher-quality care, however, as most quality measures decline at independent facilities after they are taken over by a large chain (Eliason et al., 2020).

2.6. Medicare Payment Reform

Since 1972, Medicare has extended full benefits to all patients suffering from ESRD, regardless of age. Individuals enrolled in an employer group health plan when diagnosed with ESRD retain their commercial insurance as a primary payer for 33 months, during which time Medicare acts as a secondary payer before becoming the primary payer. Medicare pays for the dialysis and anemia treatment of ESRD patients jointly under Part B. From the early 1980s to 2011, Medicare paid a composite rate of approximately $128, varying little over time and intended to cover the labor, capital, supplies, and routine lab tests associated with each dialysis treatment, with injectable drugs reimbursed separately on a fee-for-service basis.

To offset the incentives for providers to reduce their costs by providing lower-quality care following the switch to bundled payments, MIPPA also mandated the development of the QIP. The QIP reduces payments to providers that fail to meet certain clinical standards, such as hemoglobin levels and hospitalization rates. The specific criteria assessed in the QIP change from year to year, which we discuss at length in Eliason et al. (2020). In its inaugural year, 2012, the QIP standards focused on patient's urea reduction ratio (URR), a measure of the adequacy of dialysis filtration, and hemoglobin (HGB) levels. Under the QIP, Medicare reduces the annual payments to the facility between 0.5 and 2% if, for instance, the HGB levels of too many patients fall outside the regulated standards, with the size of the penalty determined by the extent of the shortfall.

2.6.1. Fee-for-Service Reimbursements for Injectable Anemia Drugs

Medicare reimbursed providers for EPO on a fee-for-service basis from 1991 through 2011. In 2005, the reimbursement rate changed from being based on the average wholesale price to the average sales price plus a six percent markup, resulting in a reimbursement rate of about $10 per 1000 IUs. The fee-for-service era saw consistent increases in EPO doses and expenditures. In 2007, spending on erythropoietin stimulating agents (ESAs), such as EPO, was about $2.7 billion (Whoriskey, 2012). Concerns that the distortionary incentives from fee-for-service reimbursements resulted in excessive costs for Medicare and harm to patients motivated policymakers to include ESRD payment reform as a part of the Medicare Improvements for Patients and Providers Act (MIPPA) in 2008.

2.6.2. Bundled Payments

MIPPA mandated the bundling of dialysis and anemia treatments into a single prospective payment. Under the new prospective payment system, which started in 2011, providers receive a single payment (initially about $230) for each dialysis treatment. This single payment is intended to cover the costs of both dialysis and injectable drugs, including EPO, that were separately billable before the reform. CMS set the reimbursement rate to reduce total federal payments to dialysis providers by 2%.

2.7. Amgen Sourcing and Supply Agreements

The large dialysis chains DaVita and Fresenius have at times partnered with Amgen, a leading producer of ESAs, to make administering drugs such as EPO more profitable. In 2011, DaVita entered into a sourcing and supply agreement with Amgen, providing DaVita with discounts and rebates for Amgen's two ESAs, EPOGEN and Aranesp (DaVita Amgen Agreement 2011). In return, DaVita agreed to purchase at least 90% of its ESAs from Amgen. This 2011 contract ran through 2018 and was renewed in 2017 to extend through 2022 (DaVita Amgen Agreement 2017). Fresenius entered into a similar sourcing and supply agreement with Amgen in 2006, extending to 2011 (Fresenius Amgen Agreement 2006). Fresenius' contract lacked minimum purchase commitments, but did secure discounts for EPOGEN and Aranesp. Following this, Fresenius now has year-to-year contracts with Amgen.

2.8. Data

The main dataset used in our analysis comes from the U.S. Renal Data System (USRDS), a clearing house that collects and manages data from a variety of sources relevant to ESRD patients and health care providers. Included in these data are Medicare claims, treatment histories, patient attributes, and annual facility surveys. In addition, CMS Form 2728, known as the Medical Evidence Form, provides rich data on the health and clinical attributes of patients when they begin dialysis. We also geocode facility addresses and extract the elevation of their locations using data from the U.S. Geological Survey (U.S. Geological Survey Center for Earth Resources Observation and Science, 2014).

We supplement these data using financial statements submitted by individual dialysis facilities to CMS each year as a part of the Healthcare Cost Reporting Information System (HCRIS). In addition to operating costs, these data include acquisition costs for drugs such as EPO. Although CMS reserves the right to audit these reports, some researchers have questioned their fidelity, particularly regarding drug acquisition costs. To address these concerns, we compared them against an independent audit of dialysis facilities conducted by the Office of the Inspector General and determined that, at least in aggregate, the costs reported in both sources are similar.

3. Descriptive Statistics and Time Trends

Table 1 presents summary statistics for our variables of interest. We limit our sample to hemodialysis patients between the ages of 18 and 100 for whom Medicare is the primary payer. We further limit our sample to observations for which we observe all patient and facility characteristics used in our later analysis. These characteristics include demographic variables like age and gender, comorbidities like diabetes and cancer, patient behaviors like smoking and drinking, and facility characteristics like chain affiliation and elevation. Although in some figures we use data from 2005–2014 to provide a wider perspective, we conduct all statistical analyses on a sample restricted to 2009–2012, a four-year window centered on the start of bundled payments and ending before the QIP had a meaningful effect on providers. After these restrictions, our sample contains approximately 10 million patient-month observations. As will be important for our IV analysis in Section 4, the elevation of facilities varies substantially, with a standard deviation of 924 ft. (summary statistics by elevation are in Appendix A).

Table 1
Patient Descriptive Statistics

	Mean	Std. Dev.
Patient Characteristics		
Predicted Mortality	0.016	0.010
Age (Years)	63.40	14.57
Months with ESRD	45.08	38.01
Black	0.385	0.487
Male	0.552	0.497
Diabetic	0.540	0.498
Hypertensive	0.906	0.292
Incident Hemoglobin	9.853	1.674
Facility Characteristics		
Facility Elevation (ft)	638.1	923.5
Independent Ownership	0.197	0.397
Resource Use		
EPO Dose (1000 IUs)	48.27	63.14
Receives Any EPO	0.755	0.430
Medicare Spending ($)		
Total	7,555	10,769
Inpatient	2,558	9,380
Dialysis	2,287	970
Part D	465	817
Outpatient	394	1,266
Health Outcomes		
Hemoglobin (g/dL)	11.12	1.22
Mortality	0.016	0.124
Hospitalizations		
Any Cause	0.1380	0.3449
Cardiac Event	0.0271	0.1625
Septicemia	0.0094	0.0965
Transfusions		
Total	0.0282	0.1655
Inpatient	0.0232	0.1504
Outpatient	0.0057	0.0750
Emergency Room	0.0001	0.0098
Unique Patients	794,396	
Patient-Months	10,077,289	

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Predicted mortality is the predicted value for each observation from a regression of mortality on patient controls and time fixed effects. Time fixed effects are not included in the prediction. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Facility Elevation is measured in feet above sea level.

3.1. Time Trends

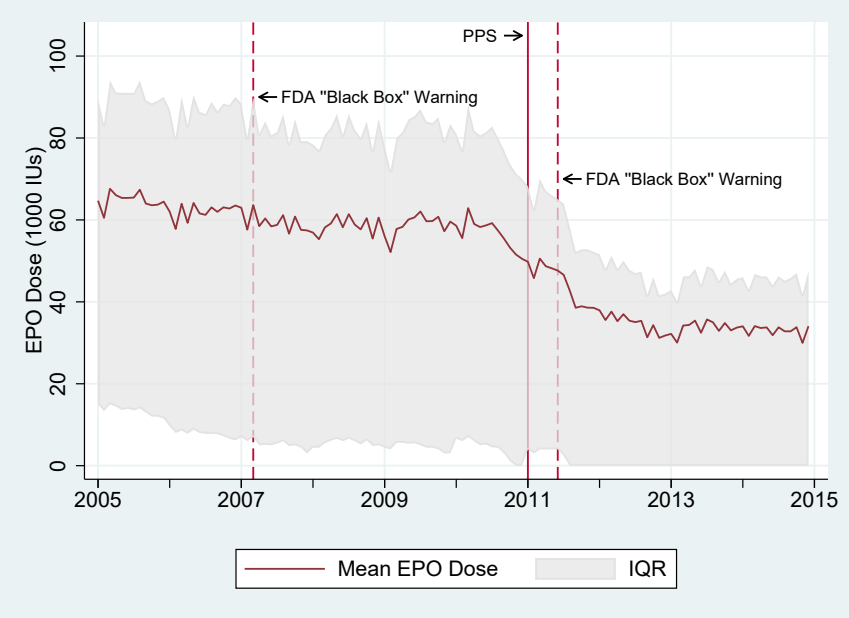
Medicare specifically targeted EPO in its 2011 payment reform, and the drug is therefore a primary mechanism through which the policy affects both the allocation of resources and patient outcomes. Figure 1 shows the evolution of average EPO doses over time, along with the interquartile range. Doses followed a slow downward trend from 2005 to 2010, then, starting midway through 2010, this downward trend accelerated abruptly until leveling off around 2013. The decline in EPO pre-dates the payment reform in 2011, perhaps reflecting an anticipatory response by providers, which may result in understated (i.e., conservative) estimates in our analysis that follows. We investigate this possibility in Appendix B, and our results are robust to changing the treatment period to include this anticipatory period as well. We also show in Appendix C that other injectable drugs followed a pattern similar to EPO's after the bundle.

Figure 2 shows the trends in HGB and transfusions over time. As EPO is prescribed to increase patients' hemoglobin, the trends correspond to those of EPO. Leading up to 2011, we see a gradual decline in HGB levels and then a more-pronounced drop consistent with the much lower doses of EPO.[6] The second panel of Figure 2 shows an uptick in transfusions that aligns with the introduction of the bundle and the decline in EPO doses.

As these trends show, providers responded to the bundle by cutting EPO doses for anemic patients, leading to a drop in HGB levels and an increase in transfusions. Although this suggests that outcomes deteriorated for at least some patients, to understand the full welfare implications of using fewer resources in dialysis treatments, we must disentangle how the change in EPO was distributed across patients. Allocative efficiency would improve, for instance, if providers concentrated the decrease in EPO among patients who receive little benefit from the drug, whereas allocative efficiency may decline if providers spread the cuts uniformly across all patients, irrespective of their individual risks and benefits from EPO. We consider this topic directly in Section 5.

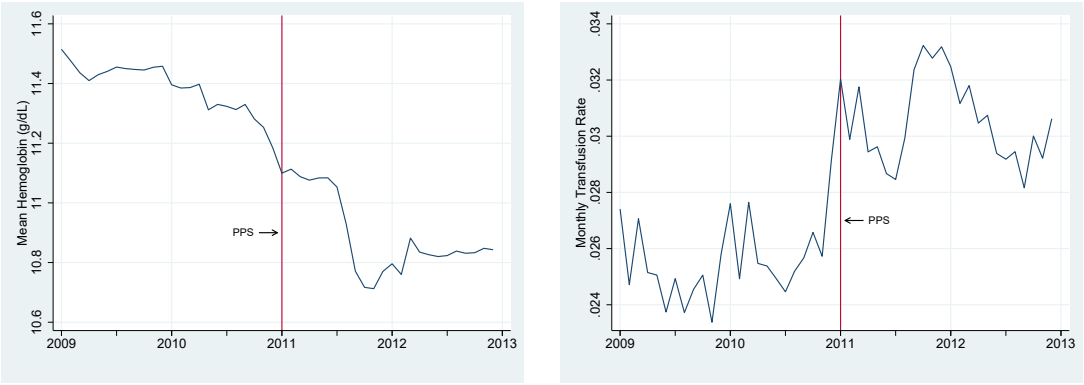
[6]There appears to be a distinct drop in hemoglobin levels in mid 2011. We explore the timing of this drop in Appendix D and attribute it to the renegotiation of the sourcing contract for EPO between a specific large dialysis chain and Amgen, as other chains and independent facilities do not exhibit the same pattern.

Figure 1
Monthly EPO Doses Over Time



Notes: An observation is a patient-month. Sample consists of observations from January 2005 to December 2014 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Vertical dashed lines indicate the release of official warnings from the FDA about the safety of high EPO doses. The solid vertical line indicates the official start date of PPS, January 2011.

Figure 2
Hemoglobin Levels and Transfusions Over Time



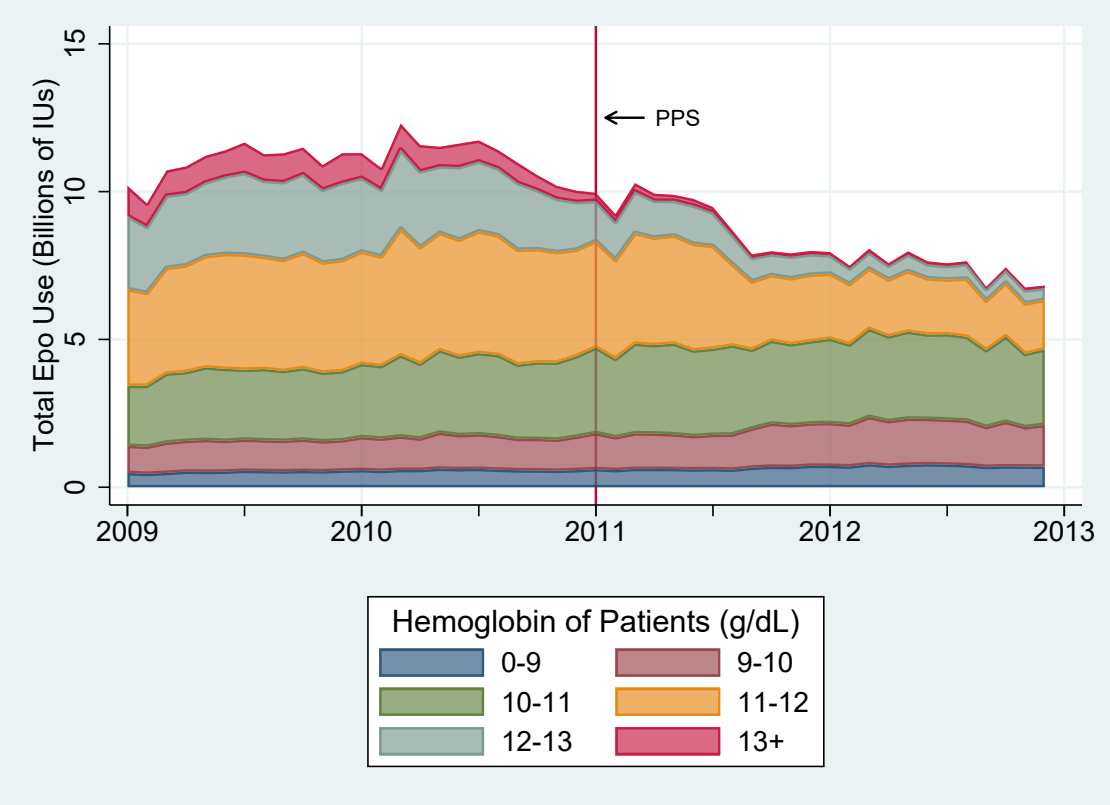
(a) Mean Hemoglobin Levels

(b) Mean Transfusion Rate

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. The solid vertical line indicates the official start date of PPS, January 2011.

Figure 3 shows how much EPO is used by patients for various HGB levels, with the largest decrease coming from patients with HGB levels above 11g/dL. As discussed above, patients with lower HGB levels benefit comparatively more from any given EPO dose, but for patients with HGB levels above 10 g/dL for women or 12 g/dL for men, EPO likely has harmful side effects that outweigh the potential benefits of the drug. Although this figure suggests that allocative efficiency improved following the payment reform, a purely descriptive approach may obscure important mechanisms. Namely, a patient's EPO dose is not exogenous, because it depends on his or her previous EPO doses as well as any idiosyncratic responsiveness to EPO. For that reason, we conduct a more thorough analysis based on our instrumental variables in Section 5.1.

Figure 3
EPO Use by HGB Level



Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. EPO doses are winsorized at the 99th percentile. Aggregate use for patients with hemoglobin in a given range is given in billions of IUs. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. The solid vertical line indicates the official start date of PPS, January 2011.

3.2. Interrupted Time Series Analysis

To quantify the effect of the payment reform on provider behavior and patient outcomes, we use an interrupted time series design, beginning with a naive specification in which we regress the variable of interest on an indicator variable for post-PPS, along with patient and facility level controls:

$$y_{ijt} = \beta_0 + \beta_1 \mathbb{1}[PPS_t = 1] + X_{ijt}\Gamma + \varepsilon_{ijt}. \tag{1}$$

Estimates of equation (1) appear in Table 2, with column (4) including controls for patient and facility characteristics, along with fixed effects for the calendar month and facility. This specification suggests a decrease in EPO doses of over 11%. In Table 3, we present results from estimating the same specification for other dependent variables, finding large changes post PPS: HGB levels decline 4.0% at the mean, transfusions increase 19.1%, overall hospitalizations drop 3.6%, hospitalizations for cardiac events fall 7.2%, and the monthly mortality rate falls 5.2%.

Although parsimonious, these simple time-series regressions are potentially biased by confounding time trends. In Figure 1, for instance, EPO doses begin falling prior to the start of the bundle. Moreover, Figure 1 suggests that the payment reform may have had both an effect on the level of EPO doses as well as the trend. In light of this, we enrich our prior specification by including a time trend interacted with PPS:

$$y_{ijt} = \beta_0 + \beta_1 t + \beta_2 \mathbb{1}[PPS_t = 1] + \beta_3 t_{Post\text{-}PPS} + X_{ijt}\Gamma + \varepsilon_{ijt}. \tag{2}$$

Equation (2) differs from equation (1) with the inclusion of two time trend terms, t and $t_{Post\text{-}PPS}$. Here, t measures the number of months since the beginning of the sample period, and $t_{Post\text{-}PPS}$ measures the number of months since the start of the PPS.[7] We therefore interpret β_1 as the average monthly change in EPO before the start of the bundle, while β_3 is the shift in this trend after the bundle.

Table 4 presents results from estimating equation (2) with EPO as the dependent variable. We find that EPO doses were declining by approximately 0.7% each month prior to the bundle, which increases in magnitude to 1.1% each month after the bundle — in addition to the immediate decrease of approximately 12.6% in average EPO doses. Compared to our results from equation (1), this suggests

[7] The variable $t_{Post\text{-}PPS}$ is set to 0 prior to the start of the bundle in January 2011.

Table 2
Effect of Bundle on EPO Dose

	(1) EPO	(2) EPO	(3) EPO	(4) EPO
PPS	-18.04***	-19.64***	-16.74***	-5.534***
	(0.242)	(0.235)	(0.414)	(0.263)
Pat/Fac Controls	0	1	1	1
Facility FE	0	0	1	1
Patient FE	0	0	0	1
Dep. Var. Mean	48.27	48.27	48.27	48.31
R-squared	0.0204	0.0784	0.136	0.532
Observations	10077289	10077289	10077264	10059269

Notes: OLS estimates from equation (1). Dependent variable is total monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. PPS is an indicator variable for January 2011 or later. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status. Further controls include month fixed effects. Facility and patient fixed effects are also included when indicated. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table 3
Effect of Bundle on Other Outcomes

	(1) HGB	(2) Transfusion	(3) Hosp., Any Cause	(4) Hosp., Cardiac Event	(5) Mortality
PPS	-0.442***	0.00538***	-0.00500***	-0.00195***	-0.000815***
	(0.00888)	(0.000201)	(0.000505)	(0.000210)	(0.000124)
Pat/Fac Controls	1	1	1	1	1
Facility FE	1	1	1	1	1
Dep. Var. Mean	11.12	0.0282	0.138	0.0272	0.0157
R-squared	0.0749	0.0118	0.0189	0.00721	0.00850
Observations	8181736	10077264	8869206	8869206	10077264

Notes: OLS estimates from equation (1). Dependent variable in column (1) is hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (2)–(5) are binary outcome variables. PPS is an indicator variable for January 2011 or later. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

the effects of the bundle on EPO doses did not become fully realized until January 2012. In Table 5, we extend the results by estimating equation (2) on other outcomes, first considering blood transfusions. Here we see a small increase in the trend of blood transfusions that starts with the introduction of the bundle and becomes more pronounced over time, which is consistent with the contemporaneous reduction in EPO doses.

For any-cause hospitalizations, we see a pre-existing downward trend. After the bundle, the magnitude of this downward trend increases, but without a significant level adjustment. Hospitalizations for cardiac events were also declining prior to the bundle, but the slope of this decline more than doubles post bundle, which is once again in line with the drop in EPO doses and the risk factors associated with the drug. By December of 2012, we find a 1.0% decrease in hospitalizations for cardiac events relative to December 2010. Finally, mortality rates were decreasing in the pre-period and declined further following the start of the bundle, though the difference is not statistically significant.

Table 4
Effect of Bundle on EPO Dose, Pre- and Post-Trends

	(1) EPO	(2) EPO	(3) EPO	(4) EPO
PPS	-6.353***	-6.592***	-6.671***	-6.106***
	(0.256)	(0.280)	(0.273)	(0.263)
Time Trend	-0.175***	-0.215***	-0.187***	-0.347***
	(0.0155)	(0.0158)	(0.0187)	(0.0582)
Post-PPS Trend Change	-0.647***	-0.687***	-0.681***	-0.708***
	(0.0227)	(0.0215)	(0.0212)	(0.0205)
Pat/Fac Controls	0	1	1	1
Facility FE	0	0	1	1
Patient FE	0	0	0	1
Dep. Var. Mean	48.27	48.27	48.27	48.31
R-squared	0.0248	0.0828	0.139	0.533
Observations	10077289	10077289	10077264	10059269

Notes: OLS estimates from equation (2). Dependent variable is total monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Facility and patient fixed effects are also included when indicated. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table 5
Effect of Bundle on Other Outcomes, Pre- and Post-Trends

	(1) HGB	(2) Transfusion	(3) Hosp., Any Cause	(4) Hosp., Cardiac Event	(5) Mortality
PPS	-0.231***	0.00481***	0.000582	0.0000238	0.0000603
	(0.00645)	(0.000289)	(0.000626)	(0.000266)	(0.000181)
Time Trend	-0.00935***	0.0000707***	-0.000173***	-0.0000868***	-0.0000397***
	(0.000354)	(0.0000155)	(0.0000373)	(0.0000157)	(0.0000103)
Post-PPS Trend Change	-0.00271***	-0.0000868***	-0.000240***	-0.0000317^{+}	-0.0000104
	(0.000420)	(0.0000209)	(0.0000467)	(0.0000192)	(0.0000120)
Pat/Fac Controls	1	1	1	1	1
Facility FE	1	1	1	1	1
Dep. Var. Mean	11.12	0.0282	0.138	0.0272	0.0157
R-squared	0.0772	0.0118	0.0189	0.00722	0.00850
Observations	8181736	10077264	8869206	8869206	10077264

Notes: OLS estimates from equation (2). Dependent variable in column (1) is hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (2)–(5) are binary outcome variables. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

4. Instrumental Variables Analysis

Our descriptive results so far suggest that EPO doses fell sharply in response to bundled payments. But because all providers experienced the same change in reimbursements at the same time, isolating the effect of the reform from other confounding, time-varying factors requires an empirical strategy built around exogenous variation in how the policy influenced some providers or patients differently than others.

4.1. Identification Strategy

Consider the effect of EPO on a health outcome, as in the following specification:

$$y_{ijt} = \beta_0 + \beta_1 EPO_{ijt} + X_{ijt}\Gamma + \varepsilon_{ijt}, \tag{3}$$

where y_{ijt} is the health outcome of patient i, treated at facility j, in month t. The main challenges with identifying the causal effect of EPO on health outcomes stem from reverse causality and simultaneity, which could bias OLS estimates in ambiguous ways. The estimates would be biased upwards, for example, if only the healthiest patients receive EPO. Or, a downward bias may result from unobserved confounds, such as rapidly deteriorating kidneys, that would lead to both high EPO doses to combat anemia as well as low survival rates due to the patient's declining health. Moreover, classical measurement error in the doses reported to Medicare would lead to attenuation bias.

To overcome these empirical challenges, we use two independent sources of variation in EPO doses within an instrumental variables regression. First, we use the time-series variation in EPO reimbursements associated with Medicare's payment policies. As Medicare applied changes uniformly to all providers, rather than targeting specific payment changes to specific facilities, this policy introduced a plausibly exogenous shock to financial incentives. Second, we use a novel physiological aspect of anemia management: patients living at higher elevations have higher baseline levels of HGB and consequently require lower doses of EPO to manage their anemia. As a result, facilities at low elevations experienced a larger shock to their EPO reimbursements than facilities at higher elevations did, and we can use the cross-sectional variation induced by patients' elevations along with the time-series variation induced by the payment reform to cleanly identify the effect of EPO on health outcomes.

We cannot simply use the payment reform and elevation as instruments directly in equation (3), however, as doing so would likely not satisfy the exclusion restriction for valid instruments. Causal inference using changes before and after Medicare introduced bundled payments would require us to assume that the policy reform only influences health outcomes through its effect on EPO. But changes in Medicare's reimbursement scheme are likely conflated with other trends, such as updated dialysis standards and related medical innovations, which would be collinear with the payment reform. As such, any nonlinear changes over time could not be addressed with time fixed effects. Similarly, just as elevation directly affects patients' HGB, it may also directly affect other health outcomes (although we have found no evidence in the medical literature suggesting that it does).

To flexibly control for time effects and to improve the strength of the first stage, we use the interaction of the post-bundle indicator variable and a facility's elevation as an instrument for EPO doses while controlling directly for time trends and elevation in our first- and second-stage regressions. Our empirical strategy of interacting one variable with time-series variation and another with cross-sectional variation

was first introduced by Card (1995) to measure the returns to education and used more recently, for example, by Nunn and Qian (2014) to study the effect of U.S. food aid on conflict in recipient countries and Bettinger et al. (2017) to study the effect of online college courses on student outcomes. Adapted to our setting, we have a first-stage specification of

$$EPO_{ijt} = \alpha_1 Elevation_j + \alpha_2 PPS_t + \alpha_3 Elevation_j \times PPS_t + X_{ijt}\Gamma + u_{ijt}, \tag{4}$$

where the instrument $Elevation_j \times PPS_t$ varies by facility and time period, allowing us to control for month-year fixed effects.

By instrumenting for EPO doses with the interaction term, our empirical strategy resembles a differences-in-differences estimation, with the first-stage estimates comparing EPO doses at facilities that typically use less of the drug due to their high elevation with those at lower elevations that typically use more of it, during the FFS era when financial incentives favored higher doses relative to the bundle period when the financial incentives flipped. As outlined in Nunn and Qian (2014), the main distinction between this strategy and a typical differences-in-differences estimation is the continuous treatment variable.

For our specification to have a causal interpretation, the interaction between a facility's elevation and Medicare's payment policy must only affect health outcomes through its influence on EPO doses, conditional on the controls. That is, the exclusion restriction in our setting requires that (i) any other mechanism through which elevation affects patients is constant over time and (ii) any other mechanism causing health outcomes to differ before and after bundled payments affects patients uniformly with respect to their elevation. As discussed above, if we were to use elevation alone as the instrument, the reduced-form slope would capture both the effect of EPO as well as other plausible mechanisms that affect health outcomes. For example, those living at higher elevations may have more-active lifestyles (e.g., hiking and skiing) that lead to better outcomes, or facilities may choose their location based on patients' potential outcomes. By interacting the two instruments, however, the reduced-form coefficient only measures how the slope between elevation and outcomes changes when facilities receive bundled payments. The main effect of elevation included in both the first and second stages differences out any other plausible mechanisms that are constant across the different payment schemes.

Although not directly testable, several pieces of evidence suggest that our empirical strategy satisfies

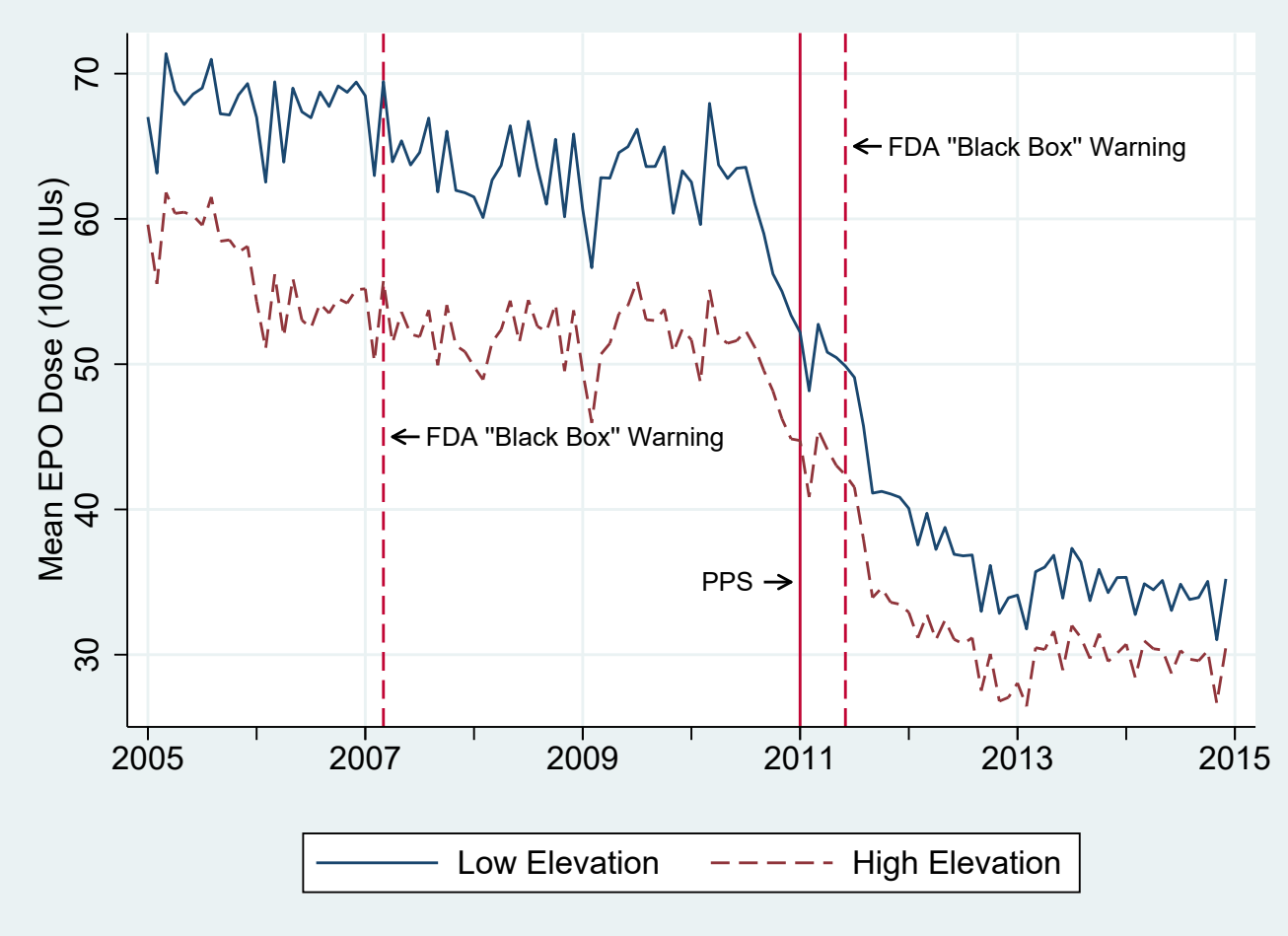
these two requirements. In the same spirit as a traditional differences-in-differences estimation, for instance, a plot of EPO doses over time for the first and fifth elevation quintiles in Figure 4 shows parallel trends in EPO doses prior to the bundle. We see that, on average, low-elevation patients received higher doses of EPO both before and after the bundle, with the difference between the two groups remaining constant during this time. After Medicare's payment reform, average EPO doses declined in both quintiles, but the decline was much greater for low-elevation patients relative to those at high elevations. As discussed in Christian and Barrett (2017), non-parallel trends would have suggested our differences-in-differences analog violated the exclusion restriction.

A related threat to our identification strategy is the presence of omitted variables that change disproportionately across elevations over time. Based on balance tables for observable patient characteristics across elevation quintiles from before and after the bundle in Appendix A, we find that, although some differences across elevations do exist and change over time, the changes are not systematically moving towards better or worse outcomes across elevations.

To assess more formally whether unobserved factors might potentially confound our analysis, we create a composite measure of a patient's health status from an OLS regression of mortality on observable patient characteristics and month-year fixed effects, which we call predicted mortality. We then use the estimated coefficients to predict a patient's mortality risk. Although we use only observable patient characteristics to construct the predicted mortality variable, predicted mortality is likely correlated with patients' unobserved characteristics that affect their health. To test if this measure changed differentially by elevation after the bundle, we estimate equation (4) with predicted mortality as the dependent variable. As shown in Table 6, we find that the differential change in predicted mortality by elevation is a precisely estimated zero, suggesting that changes in patients' underlying health are unlikely to confound our analysis.

Another violation of the exclusion restriction could come from facilities reinvesting the additional profits they earn from giving lower EPO doses after the bundle goes into effect. For instance, facilities at higher elevations use less EPO and therefore received disproportionately larger financial benefits from Medicare's switch to a prospective payment system that did not vary based on historical EPO doses; these facilities may have reinvested their financial windfall in ways that improved patient care. As shown in Table 7, however, we find no evidence that this occurred, as conventional measures of a facility's investment in providing high-quality care, such as the number of patients per staff, the number

Figure 4
Mean EPO Dosage Per Month Over Time, by Elevation



Notes: An observation is a patient-month. Sample consists of observations from January 2005 to December 2014 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. High (low) elevation denotes facility elevation in the fifth (first) quintile. This corresponds to being above 870 (below 73) feet above sea level. Vertical dashed lines indicate the release of official warnings from the FDA about the safety of high EPO doses. The solid vertical line indicates the official start date of PPS, January 2011.

Table 6
Predicted Mortality by Elevation

	(1) Predicted Mortality	(2) Predicted Mortality	(3) Predicted Mortality
Facility Elevation	0.000000198***	0.000000185**	0.000000133
	(5.81e-08)	(5.91e-08)	(0.000000170)
Elevation × PPS	-7.42e-08***	-4.95e-08*	-3.75e-08*
	(1.97e-08)	(2.29e-08)	(1.91e-08)
Year-Month FE	0	1	1
Pat/Fac Controls	0	0	0
Facility FE	0	0	1
R-squared	0.000224	0.000473	0.138
Dep. Var. Mean	0.0157	0.0157	0.0157
Observations	10077289	10077289	10077264

Notes: OLS estimates from equation (4). Dependent variable is predicted mortality. Predicted mortality is the predicted value for each observation from a regression of mortality on patient controls and time fixed effects. Time fixed effects are not included in the prediction. PPS is an indicator variable for January 2011 or later. Facility Elevation is measured in feet above sea level. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table 7
Facility Inputs by Elevation

	(1) Nurses Per Technician	(2) Patients Per Employee	(3) Patients Per Station	(4) Employees Per Station	(5) Hosp., Septicemia
Facility Elevation	-0.00000507	-0.0000504	-0.0000412	-0.00000317	-0.000000699***
	(0.0000143)	(0.0000335)	(0.0000588)	(0.0000124)	(0.000000129)
Elevation × PPS	0.00000758	0.0000230	-0.00000818	-0.00000646^{+}	3.36e-08
	(0.00000857)	(0.0000231)	(0.0000169)	(0.00000380)	(7.86e-08)
Year-Month FE	1	1	1	1	1
Pat/Fac Controls	1	1	1	1	1
Facility FE	0	0	0	0	0
R-squared	0.225	0.156	0.0870	0.0599	0.00283
Dep. Var. Mean	0.911	5.401	3.990	0.767	0.00939
Observations	242917	254307	256712	256173	10077289

Notes: OLS estimates from equation (4). PPS is an indicator variable for January 2011 or later. Facility Elevation is measured in feet above sea level. For columns (1)–(8) an observation is a facility-month. For column (9) an observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

of patients per station, and patient infection rates, do not differ by elevation, both before and after the payment reform.

4.2. Instrumental Variables Results

We present results from our first-stage estimates in Table 8, with an F-statistic of 32.7 demonstrating the instrument's relevance. Given the body's physiological response to elevation, EPO doses decrease with elevation in the expected way, but the rate of this decrease falls by half after the bundle.

Following the first-stage estimates, we recover the local average treatment effect of EPO on patient outcomes using two-stage least squares. In addition to instrumenting for EPO_{ijt}, we control for several patient covariates, month-year fixed effects, and facility fixed effects and estimate this equation for the main outcomes of interest: HGB, blood transfusions, hospitalizations, and mortality.

We begin with HGB to highlight the relevance of our empirical strategy. Based on randomized controlled trials, the FDA-approved indication for EPO is to increase HGB levels. That is, larger EPO doses have been clinically proven to have a causal effect on this outcome. The OLS specification in

Table 8
First Stage Regression

	(1) EPO	(2) EPO	(3) EPO
Facility Elevation	-0.00473***	-0.00350***	-0.00537***
	(0.000338)	(0.000398)	(0.00157)
Elevation × PPS	0.00141***	0.00131***	0.00137***
	(0.000212)	(0.000201)	(0.000198)
Year-Month FE	1	1	1
Pat/Fac Controls	0	1	1
Facility FE	0	0	1
R-squared	0.0299	0.0844	0.140
Dep. Var. Mean	48.27	48.27	48.27
Observations	10077289	10077289	10077264

Notes: OLS estimates from equation (4). Dependent variable is total monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. PPS is an indicator variable for January 2011 or later. Facility Elevation is measured in feet above sea level. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table 9
The Effect of EPO on Hemoglobin Levels and Transfusions

	HGB		Transfusion	
	(1) OLS	(2) IV	(3) OLS	(4) IV
EPO	-0.00308***	0.0214***	0.000134***	-0.000586***
	(0.0000258)	(0.00558)	(0.00000257)	(0.000157)
Year-Month FE	1	1	1	1
Pat/Fac Controls	1	1	1	1
Facility FE	1	1	1	1
Dep. Var. Mean	11.12	11.12	0.0282	0.0282
Observations	8181736	8181736	10077264	10077264
First-Stage F-statistic		32.73		48.24

Notes: OLS and IV estimates from equation (3). Dependent variable in columns (1)–(2) is hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (3)–(4) is a binary outcome variable for receiving a blood transfusion. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table 9, however, shows the opposite effect, which reflects the nonrandom assignment of EPO: more-anemic patients with lower HGB levels tend to be prescribed higher doses of EPO, inducing a negative correlation between HGB and EPO if relevant patient attributes are not observed in the data. Our IV strategy corrects for endogenous EPO doses, as shown in column (2). Increasing EPO doses by 1000 IUs per month increases a patient's HGB by 0.214 g/DL, on average, confirming the established medical fact that EPO effectively treats anemia. Table 9 also shows results with transfusions as the dependent variable. Similar to the results for HGB, the OLS coefficient suggests that EPO is associated with a need for more blood transfusions, once again contradicting established medical evidence. As with HGB, correcting for endogenous dosing decisions using our IV strategy reveals that larger EPO doses do indeed reduce the need for transfusions.

We show in Table 10 that larger EPO doses lead to more hospitalizations for cardiac events and higher mortality rates. For both all-cause and cardiac hospitalizations, the OLS results suggest a positive

Table 10
The Effect of EPO on Hospitalizations and Mortality

	Hosp., Any Cause		Hosp., Cardiac Event		Hosp., Septicemia		Mortality	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
EPO	0.000163***	0.000205	0.0000167***	0.000185+	9.28e-08	0.0000358	-0.000115***	0.000129*
	(0.00000357)	(0.000254)	(0.00000124)	(0.0000962)	(0.000000617)	(0.0000549)	(0.000000910)	(0.0000644)
Year-Month FE	1	1	1	1	1	1	1	1
Pat/Fac Controls	1	1	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1	1	1
Dep. Var. Mean	0.138	0.138	0.0271	0.0271	0.00939	0.00939	0.0157	0.0157
Observations	10077264	10077264	10077264	10077264	10077264	10077264	10077264	10077264
First-Stage F-statistic		48.24		48.24		48.24		48.24

Notes: OLS and IV estimates from equation (3). Dependent variables are binary outcomes. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Standard errors clustered by facility are in parentheses. +, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

correlation with EPO doses, but this effect diminishes in our IV specification, becoming statistically insignificant for all-cause hospitalizations. For mortality, the OLS estimates show a statistically significant, negative correlation with EPO, but the effect becomes positive while remaining statistically significant when we include our instruments. Interpreted as a local average treatment effect, our IV estimates suggest that the compliers — those patients whose EPO doses changed as a result of the instrument — had a 14.1% higher death rate during the pre-bundle period from excessive EPO doses.

As a placebo test, we also estimate equation (3) with septicemia, a severe blood infection, as the dependent variable. Because septicemia results from poor cleaning protocols at facilities and has no known relation to EPO, a statistically significant effect of EPO on septicemia would suggest the presence of a confounding variable in our analysis. As shown in Table 10, however, we do not find a causal effect of EPO on septicemia in our IV specification.

Taken together, our results highlight the tradeoffs associated with using EPO. Although EPO effectively treats patients' anemia, as reflected in higher HGB levels and fewer blood transfusions, these improvements must be weighed against a higher risk of cardiac events and dying.

5. Changes in the Allocation of EPO

Because Medicare primarily uses bundled payments to curtail providers' inefficient use of resources, the sharp drop in EPO following the payment reform in dialysis ostensibly achieved this aim. If facilities reduced EPO doses indiscriminately across all patients, however, the move to bundled payments may

have been less effective than if they had focused their cuts on those patients who receive little benefit from the drug. To assess the bundle's impact on allocative efficiency, we extend our instrumental variable analysis to classify patients based on how responsive they are to EPO, in the sense that a given dose of EPO will have a large effect on some patients' HGB levels and need for transfusions but only a small effect on others'. If providers concentrated their cuts on the latter group, then this suggests that the bundle increased allocative efficiency.[8]

5.1. Predicting Patients' Response to EPO

Consider some patient health outcome, Y_{ijt}, the depends on the main input, EPO (E_{ijt}), as well as patient attributes like gender and age (X_{it}) and provider characteristics like chain affiliation (F_{jt}), in the following way:

$$Y_{ijt} = f(E_{ijt}, X_{it}, F_{jt}). \tag{5}$$

We parameterize f as a linear function of EPO doses and patient attributes, where EPO and patient attributes are fully interacted, so that[9]

$$Y_{ijt} = \beta_0 + \beta_1 E_{ijt} + \beta_2 X_{it} + \beta_3 E_{ijt} \times X_{it} + \beta_4 F_{jt} + \varepsilon_{ijt}, \tag{6}$$

which allows the marginal effects of EPO to vary based on patient attributes, with

$$\frac{\partial Y_{ijt}}{\partial E_{ijt}} = \beta_1 + \beta_3 X_{ijt}. \tag{7}$$

[8] A formal analysis of allocative efficiency would require us to fully specify a welfare function while making strong assumptions about the tradeoffs associated with high EPO doses and the shape of the welfare function. Rather than take this approach, we look for evidence that the reallocation increased the returns to EPO, focusing specifically on HGB and transfusions.

[9] This specification does not allow the returns from EPO to vary by facility characteristics, only by patient attributes. Different facilities are allowed to have production possibilities frontiers that are level-shifts of one another, but the slope does not change. Put differently, if a patient were to move from one facility to another, the level of the health outcome Y_{ijt} could change, but the marginal effect of EPO $\frac{\partial Y_{ijt}}{\partial E_{ijt}}$ could not. This simplification reflects the physiological and institutional details of anemia treatment. The EPO molecule is the same across providers, and a patient's physiological reaction to a given amount of that molecule will be the same irrespective of which facility administers it. For any given patient, facilities have limited control over the effectiveness of EPO, although they can control the efficiency with which they use EPO by deciding whom to treat and with how much.

In our analysis, we focus on two dependent variables, HGB levels and blood transfusion rates. A patient's HGB level is a direct, though surrogate, measure of anemia that is readily available to providers during treatment, whereas reducing blood transfusions is a primary goal of treating anemia but more difficult to target directly. In this section, we focus on blood transfusion, but provide a similar analysis of HGB levels in the appendix.

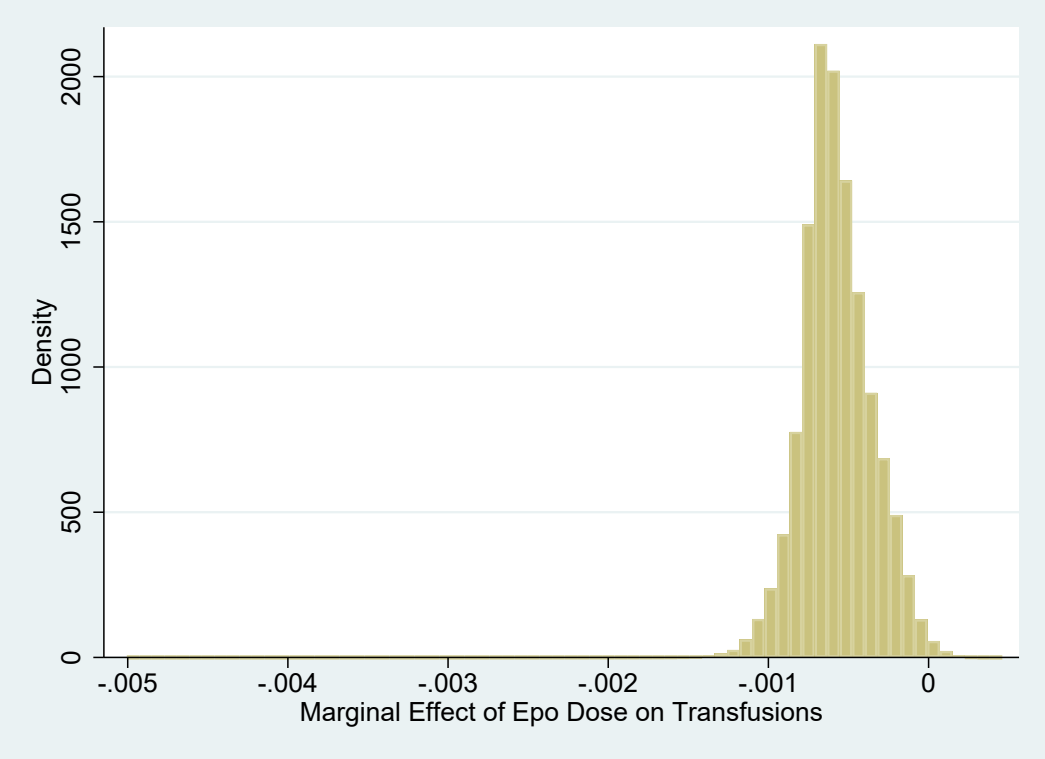
To estimate equation (6), we extend our instrumental variable strategy from Section 4. As before, we estimate equation (6) using two-stage least squares where we treat E_{ijt} as an endogenous variable. The main difference from our approach in Section 4 is that we now interact E_{ijt} with all patient attributes in the data. To instrument for these interactions, we use the natural extension of our original instrument, elevation interacted with the bundle. That is, we interact our original instrument with each patient attribute and use these as a new set of instruments. For example, the difference in the marginal effect of EPO for men and women is instrumented by the differential change for men and women after the start of the bundle and across elevations. Using analogous instruments for all components of $E_{ijt} \times X_{it}$, we estimate equation (6) and obtain the marginal effects outlined in equation (7) for each patient-month observation based on their observed attributes.

5.2. The Allocation of EPO and Its Effect on Blood Transfusions

Figure 5 shows the distribution of the marginal effect of EPO on blood transfusion rates for all patient-month observations. The average predicted marginal effect of EPO on transfusions is -0.0006, which is identical to the local average treatment effect estimated in Section 4, with the distribution largely falling between -0.001 and 0. The wide variation in patients' responsiveness to EPO has important practical implications: for a patient with a marginal effect one standard deviation above the mean, the average EPO dose will decrease the likelihood of needing a transfusion by 0.02 percentage points, whereas the same dose for a patient one standard deviation below the mean will decrease the likelihood of needing a transfusion by twice as much. Most of the variation in marginal effects is between patients, with a given patient's responsiveness to EPO changing very little over time. In light of this persistence, we construct a time-invariant, patient-level measure of EPO responsiveness to evaluate allocative efficiency before and after the bundle. For this, we use the average of the patient-month predicted marginal effects obtained from estimating equation (6).

Figure 5

Histogram of Predicted Marginal Effects ($\widehat{\frac{\partial Y_{ijt}}{\partial E_{ijt}}}$) of EPO on Transfusions



Notes: Predicted values are defined by equation (7) and come from IV estimates of equation (6). An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later.

To make it easer to interpret our results, we multiply the average marginal effects by -1 (since the benefit from EPO is a negative marginal effect on transfusions) and then normalize it by converting it to a Z-score, which we map to a patient's EPO-responsiveness type. Patients who are very responsive to EPO are those with a more negative average marginal effect, whereas patients who are not very responsive to EPO are those with average marginal effects close to zero. Put differently, EPO is more effective at reducing transfusion rates for patients who are highly responsive to the drug.

The patients most responsive to EPO have different observable characteristics than those who are less responsive. Table 11 compares the attributes of patients across responsiveness quintiles. Patients in the first quintile are the least responsive to EPO, meaning that EPO has a small effect on their transfusion rates. Along some dimensions, we see a negative association between how much EPO reduces the need for blood transfusions and the patient's observable health status. Patients who respond the least to EPO (i.e., those in the lowest quintiles) have the highest predicted and unadjusted mortality rates, have more hospitalizations, are older, and have more severe anemia as measured by incident hemoglobin (i.e., their HGB level before beginning dialysis). Throughout the sample, these unresponsive patients also receive the largest EPO doses yet still require the most transfusions, suggesting that EPO is largely wasted on them (it could be that their transfusion rates would have been even higher had they not received such large EPO doses, but we will soon show that this is not the case).

In Figure 6, we decompose the trends in EPO over time by the quintiles of responsiveness. We term patients from the first quintile for whom the effect of EPO is close to zero as "unresponsive" and patients from the fifth quintile as "responsive." Figure 6 shows that, although EPO doses fell for both groups, the drop was greater for the unresponsive patients. Prior to the bundle, unresponsive patients actually received more EPO than the responsive patients who benefitted more from the drug. The tendency to give more EPO to patients receiving little benefit from it diminishes after the bundle, as the two groups converge in terms of both doses and the likelihood of receiving any EPO. The drop in EPO only affects the transfusion rates for the responsive group, however, as shown in panel (d). Transfusion rates continued a downward trend for the unresponsive patients despite the fact that they had a larger drop in EPO compared to the responsive patients, for whom transfusions increased. In that way, the bundle appears to have decreased the wasteful use of EPO, as the unresponsive patients experienced large decreases in their doses with no corresponding increase in transfusions, which we interpret as an increase in allocative efficiency. On the other hand, EPO doses arguably fell too far for the responsive

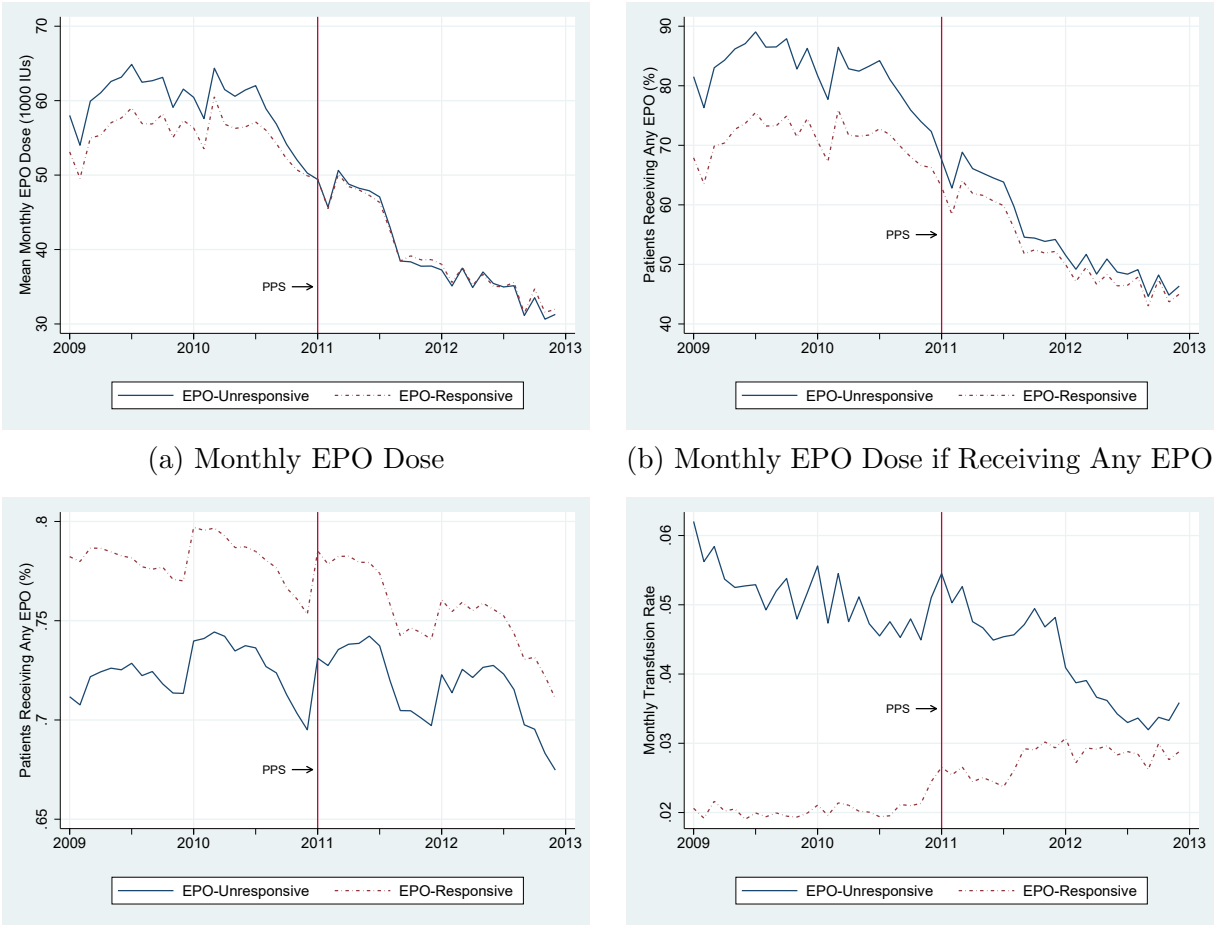
Table 11
Descriptive Statistics by Responsiveness of Transfusion Rate to EPO

	EPO Sensitivity Quintile				
	First	Second	Third	Fourth	Fifth
Patient Characteristics					
Predicted Mortality	0.021	0.016	0.014	0.014	0.016
Age (Years)	68.08	63.39	62.30	62.10	63.72
Months with ESRD	22.75	45.05	45.46	43.73	44.11
Black	0.352	0.462	0.462	0.420	0.226
Male	0.645	0.613	0.579	0.513	0.461
Diabetic	0.520	0.516	0.516	0.522	0.556
Hypertensive	0.966	0.969	0.964	0.939	0.741
Incident Hemoglobin	9.696	9.633	9.776	10.013	10.308
Facility Characteristics					
Facility Elevation (ft)	681.8	640.1	625.6	634.2	629.7
Independent Ownership	0.224	0.210	0.213	0.211	0.234
Resource Use					
Epo Dose (1000 IUs)	61.20	60.51	59.24	58.38	55.90
Receives Any EPO	0.720	0.769	0.782	0.780	0.780
Medicare Spending ($)					
Total	10,117	7,572	7,094	6,976	6,964
Inpatient	4,459	2,631	2,305	2,252	2,258
Dialysis	2,079	2,257	2,279	2,271	2,241
Part D	321	408	429	434	439
Outpatient	454	379	355	336	344
Health Outcomes					
Hemoglobin (g/dL)	11.30	11.46	11.47	11.47	11.47
Mortality	0.042	0.014	0.012	0.013	0.014
Hospitalizations					
Any Cause	0.2243	0.1444	0.1302	0.1285	0.1304
Cardiac Event	0.0446	0.0286	0.0261	0.0264	0.0280
Septicemia	0.0195	0.0085	0.0070	0.0070	0.0073
Transfusions					
Total	0.0533	0.0250	0.0208	0.0197	0.0199
Inpatient	0.0445	0.0207	0.0169	0.0159	0.0159
Outpatient	0.0103	0.0048	0.0043	0.0042	0.0044
Emergency Room	0.0002	0.0001	0.0001	0.0001	0.0001
Unique Patients	44,996	46,812	52,642	55,423	56,631
Patient-Months	285,141	422,004	519,269	555,871	568,157

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Predicted mortality is the predicted value for each observation from a regression of mortality on patient controls and time fixed effects. Time fixed effects are not included in the prediction. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Facility Elevation is measured in feet above sea level. Predicted values are defined by equation (7) and come from IV estimates of equation (6).

patients, as their transfusion rates went up after the bundle. We still interpret this as an increase in allocative efficiency overall because the responsive patients would have experienced an even larger increase in transfusions had they received the same proportional cuts in EPO that the unresponsive patients did. In other words, conditional on the absolute decline in EPO doses following the bundle, facilities reallocated doses in a way that resulted in better outcomes than if they had maintained the same relative doses across patients as before.

Figure 6
Key Variables Over Time by Responsiveness of Transfusion Rates to EPO



(a) Monthly EPO Dose

(b) Monthly EPO Dose if Receiving Any EPO

(c) Share of Patients Receiving Any EPO

(d) Transfusion Rate

Notes: "EPO-responsive" ("EPO-unresponsive") refers to patients with average estimated marginal effects of EPO on transfusions in the fifth (first) quintile. This corresponds to being at least 0.78 standard deviations below (0.73 standard deviations above) the average estimated marginal effect. Predicted values come from IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. The solid vertical line indicates the official start date of PPS, January 2011.

To quantify how the bundle differentially affected patients based on their responsiveness to EPO, we estimate the following regression:

$$Y_{ijt} = \beta_0 + \beta_1 z_{\widehat{\frac{\partial Y_{ijt}}{\partial E_{ijt}}}} + \beta_2 \mathbb{1}[PPS_t = 1] + \beta_3 z_{\widehat{\frac{\partial Y_{ijt}}{\partial E_{ijt}}}} \times \mathbb{1}[PPS_t = 1] + \beta_4 t + X_{ijt}\Gamma + \varepsilon_{ijt}, \tag{8}$$

where $z_{\widehat{\frac{\partial Y_{ijt}}{\partial E_{ijt}}}}$ denotes our standardized measure of EPO-responsiveness with respect to blood transfusions. We consider two dependent variables: EPO, which describes the intensity of treatment, and transfusion rates, which describes the resulting health outcome. We include facility fixed effects and facility-level controls in X_{ijt}, and all other variables are defined as in Section 3.1.

Columns (1) and (2) in Table 12 show that, prior to the bundle, less-responsive patients received larger EPO doses. The pre-bundle gradient suggests that providers wasted EPO on these unresponsive patients, as their transfusion rates did not vary with the dose administered, shown clearly in a plot of the response across patient-types in panel (a) of Figure A4 in the appendix. Although these patients appear to have gotten no direct benefit from the large doses of EPO, the facilities themselves benefitted from the associated fee-for-service reimbursements. After the bundle, EPO doses declined overall, with providers reallocating EPO from unresponsive patients to those who benefit more from the drug, as seen in the positive coefficient on the interaction between the EPO-responsiveness Z-score and the PPS indicator variable.

In columns (3) and (4), we show that, prior to the bundle, patients who benefited more from EPO were less likely to need blood transfusions. After the bundle, the transfusion rate rose overall, with patients who have the largest response to EPO experiencing the largest increase — the same patients who experienced the smallest decrease in EPO doses. Taken together, these results show that the decrease in EPO following the payment reform was so large that it caused comparatively more transfusions among the EPO-responsive patients despite the reallocation of EPO towards them from the unresponsive patients.

Table 12
DIFFERENCE IN EPO BY THE RESPONSIVENESS OF TRANSFUSIONS TO EPO

	(1) EPO	(2) EPO	(3) Transfusion	(4) Transfusion
EPO-Responsiveness Z-Score	-1.281***	-1.110***	-0.00988***	-0.00985***
	(0.104)	(0.104)	(0.000165)	(0.000165)
PPS	-6.189***		0.00484***	
	(0.272)		(0.000292)	
EPO-Responsiveness Z-Score × PPS	1.722***	1.361***	0.00421***	0.00416***
	(0.105)	(0.105)	(0.000180)	(0.000180)
Time Trend	-0.517***		-0.0000786***	
	(0.0145)		(0.0000123)	
Patient Controls	0	0	0	0
Facility Controls	1	1	1	1
Month FE and Trend	1	0	1	0
Year-Month FE	0	1	0	1
Facility FE	1	1	1	1
R-squared	0.123	0.125	0.00916	0.00919
Dep. Var. Mean	48.27	48.27	0.0282	0.0282
Observations	10077264	10077264	10077264	10077264

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Dependent variables in columns (3)–(4) is a binary measure of transfusions. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

In Table 13, we present similar results for other health outcomes that may have influenced facilities' decisions about patients' EPO doses. In columns (1) and (2), we find that HGB levels fell more for EPO-responsive patients, consistent with their increase in transfusions. We also find that EPO-responsive patients experienced a relatively larger increase in hospitalization and mortality rates, bringing them closer to the rates of less-responsive patients. These results further indicate that the decrease in EPO, despite being concentrated among unresponsive patients, did relatively more harm to the health outcomes of the more-responsive patients.

Table 13
Difference in Other Outcomes by Responsiveness of Transfusions to EPO

	HGB		Hosp., Any Cause		Hosp., Cardiac Event		Mortality	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPO-Responsiveness Z-Score	0.0449***	0.0454***	-0.0264***	-0.0263***	-0.00457***	-0.00457***	-0.00826***	-0.00826***
	(0.00137)	(0.00137)	(0.000345)	(0.000345)	(0.000120)	(0.000120)	(0.000108)	(0.000108)
PPS	-0.231***		0.00108+		0.000124		0.0000216	
	(0.00652)		(0.000588)		(0.000249)		(0.000182)	
EPO-Responsiveness Z-Score × PPS	-0.0178***	-0.0184***	0.0113***	0.0112***	0.00229***	0.00228***	0.00442***	0.00442***
	(0.00178)	(0.00179)	(0.000353)	(0.000354)	(0.000138)	(0.000138)	(0.000110)	(0.000111)
Time Trend	-0.0103***		-0.000603***		-0.000163***		-0.000109***	
	(0.000328)		(0.0000259)		(0.0000112)		(0.00000805)	
Patient Controls	0	0	0	0	0	0	0	0
Facility Controls	1	1	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1	0	1
Facility FE	1	1	1	1	1	1	1	1
R-squared	0.0718	0.0752	0.0139	0.0139	0.00417	0.00418	0.00485	0.00486
Dep. Var. Mean	11.12	11.12	0.138	0.138	0.0271	0.0271	0.0157	0.0157
Observations	8181736	8181736	10077264	10077264	10077264	10077264	10077264	10077264

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (3)–(8) are binary measures. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. +, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

The reallocation of EPO across responsive and unresponsive patients directly affected Medicare spending, as shown in Table 14. Before the bundle, inpatient, outpatient, and overall Medicare spending were much lower for responsive patients. As a result, their spending for dialysis and Part D claims were higher, because unresponsive patients missed more dialysis sessions while in the hospital. After the bundle, spending converged in all categories, nearing parity for dialysis. Once again, this reflects a better allocation of resources: spending fell and outcomes improved sharply for patients who do not respond to EPO compared to a much flatter change on both dimensions for those patients who do.

Table 14
Difference in Medicare Spending by Responsiveness of Transfusions to EPO

	Inpatient		Outpatient		Dialysis		Part D		Total	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
EPO-Responsiveness Z-Score	-638.3***	-634.3***	-40.57***	-40.50***	37.72***	36.41***	40.33***	39.74***	-940.1***	-933.9***
	(9.074)	(9.055)	(0.975)	(0.973)	(1.533)	(1.530)	(1.205)	(1.202)	(12.42)	(12.39)
PPS	25.62		-4.350*		5.326		9.254***		3.096	
	(15.78)		(2.199)		(3.959)		(1.525)		(20.22)	
EPO-Responsiveness Z-Score × PPS	346.0***	337.3***	1.457	1.242	-35.43***	-32.65***	12.62***	13.87***	438.4***	424.8***
	(9.417)	(9.438)	(1.463)	(1.473)	(1.653)	(1.650)	(1.272)	(1.274)	(12.37)	(12.41)
Time Trend	-11.85***		1.277***		3.887***		3.306***		-9.507***	
	(0.694)		(0.111)		(0.167)		(0.0826)		(0.926)	
Patient Controls	0	0	0	0	0	0	0	0	0	0
Facility Controls	1	1	1	1	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1	0	1	0	1
Facility FE	1	1	1	1	1	1	1	1	1	1
R-squared	0.00995	0.0100	0.0143	0.0144	0.0557	0.0579	0.0388	0.0390	0.0215	0.0217
Dep. Var. Mean	2557.5	2557.5	393.7	393.7	2286.8	2286.8	465.2	465.2	7555.4	7555.4
Observations	9771287	9771287	9771287	9771287	9771287	9771287	9771287	9771287	9771287	9771287

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (3)–(8) are binary measures. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

5.3. Differences in Allocative Efficiency Across Chains

Chain-owned facilities behave differently than independent facilities with respect to EPO, both before and after the bundle. Interacting the chain status of each facility with equation (8), we show in Table 15 that chains used much more EPO in the pre-bundle period and had a larger difference in doses across responsive and unresponsive patients. That chains gave relatively more EPO to unresponsive patients suggests they wasted more resources, as the higher doses did not lead to correspondingly lower transfusion rates. After the bundle, EPO doses decreased substantially at both chain and independent facilities, with chains cutting doses by nearly twice as much.

Table 15
Difference in EPO by Responsiveness of Transfusions to EPO and Chain Status

	(1) EPO	(2) EPO	(3) Transfusion	(4) Transfusion
Chain Ownership	10.38***	10.98***	-0.00128	-0.00117
	(1.760)	(1.762)	(0.00104)	(0.000985)
EPO-Responsiveness Z-Score	-0.490**	-1.017***	-0.0103***	-0.0104***
	(0.177)	(0.177)	(0.000356)	(0.000350)
EPO-Responsiveness Z-Score × Chain	-0.997***	-0.120	0.000586	0.000654+
	(0.215)	(0.214)	(0.000402)	(0.000394)
PPS	-2.715***		0.00504***	
	(0.715)		(0.000647)	
PPS × Chain	-4.307***		-0.000272	
	(0.748)		(0.000697)	
EPO-Responsiveness Z-Score × PPS	0.677**	0.472*	0.00420***	0.00417***
	(0.229)	(0.238)	(0.000406)	(0.000404)
EPO-Responsiveness Z-Score × PPS × Chain	1.305***	1.101***	-0.0000186	-0.0000400
	(0.257)	(0.265)	(0.000454)	(0.000451)
Time Trend	-0.287***		-0.0000565*	
	(0.0252)		(0.0000243)	
Time Trend × Chain	-0.282***		-0.0000240	
	(0.0240)		(0.0000258)	
Patient Controls	0	0	0	0
Facility Controls	1	1	1	1
Month FE and Trend	1	0	1	0
Year-Month FE	0	1	0	1
Facility FE	1	1	1	1
R-squared	0.124	0.125	0.00916	0.00919
Dep. Var. Mean	48.27	48.27	0.0282	0.0282
Observations	10077264	10077264	10077264	10077264

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Dependent variables in columns (3)–(4) is a binary measure of transfusions. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. Transfusion rate is the dependent variable of this regression. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. +, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

In contrast to independent facilities, where the difference in EPO doses for responsive and unresponsive patients changed only slightly after the bundle, chains reduced EPO doses significantly more for unresponsive patients. The lower doses caused transfusion rates to increase at independent and chain facilities at about the same rate, with the larger cuts for the least-responsive patients having an imperceptible effect on their monthly transfusion rates. Because chains reallocated more EPO away from unresponsive patients without increasing their need for transfusions, we interpret this as an improvement in allocative efficiency, perhaps reflecting a more-concerted effort at chain-owned facilities to reduce EPO costs once they no longer received fee-for-service reimbursements for injectable drugs.

6. Conclusion

Dialysis facilities sharply reduced their use of injectable drugs after Medicare stopped reimbursing them on a fee-for-service basis. Once bundled payments made these drugs a marginal cost for providers, they responded by cutting doses the most for those patients who receive little benefit from the drug. In so doing, dialysis facilities revealed the extent of their wasteful behavior prior to the payment reform: health outcomes actually *improved* for the group of patients who experienced the largest drop in EPO.

Beyond dialysis, our results contribute to the broader discussion of alternative payment models within health care. Over the past decade, Medicare has responded to allegations that their traditional fee-for-service system resulted in an excessive use of resources — as we showed for injectable anemia drugs in dialysis — by promoting accountable care organizations and bundled payments, to the point that these alternative payment models now constitute over 30% of Traditional Medicare spending (Shatto, 2016). We add to the many observational studies of this transition by focusing on the causal effects of bundled payments. Using a research design built around the exogenous variation in EPO doses stemming from a patient's elevation, we show that allocative efficiency improved due to bundled payments. Other settings, like Medicare's bundled payments program for hip and knee replacements, known as Comprehensive Care for Joint Replacement, have shown more modest reallocations (Einav et al., 2020). As a chronic condition with potentially more scope for reducing the amount of resources used during treatment and over time, dialysis providers may be more willing to change their practice style in response to a bundle.

To counteract the incentive to undertreat patients, Medicare implemented the Quality Incentive

Program in conjunction with the payment reform. This program, the first of its kind in Medicare, reduces payments by up to two percent for dialysis facilities that fail to meet certain performance standards. Although in this paper we deliberately ended our sample at the end of 2012, before the financial penalties would have had much influence on dialysis facilities, in subsequent work, Eliason et al. (2020), we consider the complementary effect of imposing minimum quality standards along with an alternative payment model.

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APPENDIX

NOT FOR PUBLICATION

A. Summary Statistics by Elevation

We provide additional summary statistics from our data by quintile of facility elevation. We see that patients at higher elevations tend to be less healthy than those at lower elevations, but these differences do not change following the start of bundled payments. We do, however, see outcomes change differentially by elevation, providing descriptive evidence the policy had different effects depending on a patient's elevation.

Table A1
Patient Descriptive Statistics by Elevation

	Elevation Quintile				
	First	Second	Third	Fourth	Fifth
Patient Characteristics					
Predicted Mortality	0.015	0.015	0.015	0.016	0.017
Age (Years)	63.41	63.60	62.91	63.53	63.57
Months with ESRD	45.59	45.35	45.72	45.49	43.22
Black	0.447	0.440	0.452	0.375	0.211
Male	0.553	0.548	0.545	0.551	0.562
Diabetic	0.526	0.534	0.536	0.544	0.560
Hypertensive	0.910	0.906	0.909	0.905	0.900
Incident Hemoglobin	9.755	9.786	9.806	9.901	10.018
Facility Characteristics					
Facility Elevation (ft)	29.4	143.7	436.1	713.5	1875.9
Independent Ownership	0.185	0.183	0.177	0.231	0.208
Resource Use					
Epo Dose (1000 IUs)	51.26	50.01	50.68	46.61	42.70
Receives Any EPO	0.791	0.784	0.779	0.725	0.694
Medicare Spending ($)					
Total	8,019	8,042	7,342	7,389	6,980
Inpatient	2,788	2,759	2,443	2,469	2,328
Dialysis	2,320	2,372	2,266	2,262	2,215
Part D	499	493	464	442	428
Outpatient	352	389	410	424	394
Health Outcomes					
Hemoglobin (g/dL)	11.11	11.11	11.12	11.12	11.16
Mortality	0.015	0.015	0.015	0.016	0.017
Hospitalizations					
Any Cause	0.1406	0.1382	0.1355	0.1418	0.1340
Cardiac Event	0.0280	0.0281	0.0268	0.0280	0.0248
Septicemia	0.0097	0.0095	0.0091	0.0095	0.0090
Transfusions					
Total	0.0297	0.0282	0.0278	0.0281	0.0270
Inpatient	0.0255	0.0242	0.0226	0.0225	0.0210
Outpatient	0.0047	0.0045	0.0059	0.0064	0.0068
Emergency Room	0.0001	0.0001	0.0001	0.0001	0.0001
Unique Patients	182,367	177,043	181,696	184,327	185,625
Patient-Months	2,043,637	1,989,978	2,033,229	2,000,408	2,010,037

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Predicted mortality is the predicted value for each observation from a regression of mortality on patient controls and time fixed effects. Time fixed effects are not included in the prediction. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Facility Elevation is measured in feet above sea level. The cut points between elevation quintiles are 73, 260, 599, and 870 feet above sea level.

Table A2
PATIENT DESCRIPTIVE STATISTICS BY ELEVATION, PRE-BUNDLE

	Elevation Quintile				
	First	Second	Third	Fourth	Fifth
Patient Characteristics					
Predicted Mortality	0.015	0.015	0.015	0.017	0.017
Age (Years)	63.44	63.57	62.98	63.65	63.83
Months with ESRD	42.29	42.25	42.39	42.53	40.03
Black	0.446	0.438	0.447	0.370	0.207
Male	0.550	0.546	0.543	0.549	0.559
Diabetic	0.510	0.524	0.524	0.531	0.549
Hypertensive	0.908	0.905	0.910	0.904	0.899
Incident Hemoglobin	9.836	9.855	9.866	9.975	10.094
Facility Characteristics					
Facility Elevation (ft)	29.8	143.3	437.8	714.2	1868.8
Independent Ownership	0.199	0.202	0.195	0.267	0.229
Resource Use					
Epo Dose (1000 IUs)	62.89	61.34	61.77	55.37	52.01
Receives Any EPO	0.813	0.802	0.795	0.732	0.713
Medicare Spending ($)					
Total	8,016	7,999	7,305	7,299	6,801
Inpatient	2,846	2,818	2,492	2,520	2,320
Dialysis	2,283	2,326	2,236	2,211	2,145
Part D	442	445	417	394	382
Outpatient	332	364	377	387	361
Health Outcomes					
Hemoglobin (g/dL)	11.46	11.45	11.44	11.45	11.46
Mortality	0.016	0.016	0.017	0.018	0.017
Hospitalizations					
Any Cause	0.1471	0.1446	0.1420	0.1463	0.1391
Cardiac Event	0.0307	0.0303	0.0289	0.0300	0.0267
Septicemia	0.0093	0.0091	0.0088	0.0089	0.0084
Transfusions					
Total	0.0256	0.0249	0.0247	0.0256	0.0244
Inpatient	0.0219	0.0211	0.0201	0.0203	0.0188
Outpatient	0.0042	0.0042	0.0051	0.0059	0.0063
Emergency Room	0.0001	0.0001	0.0001	0.0001	0.0001
Unique Patients	54,576	52,150	54,661	53,701	54,001
Patient-Months	477,695	457,844	478,139	467,866	468,898

Notes: An observation is a patient-month. Sample consists of observations from January to December 2009 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Predicted mortality is the predicted value for each observation from a regression of mortality on patient controls and time fixed effects. Time fixed effects are not included in the prediction. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Facility Elevation is measured in feet above sea level. The cut points between elevation quintiles are 73, 260, 599, and 870 feet above sea level.

Table A3
PATIENT DESCRIPTIVE STATISTICS BY ELEVATION, POST-BUNDLE

	Elevation Quintile				
	First	Second	Third	Fourth	Fifth
Patient Characteristics					
Predicted Mortality	0.015	0.015	0.015	0.016	0.016
Age (Years)	63.37	63.63	62.85	63.35	63.33
Months with ESRD	48.98	48.68	49.02	48.59	46.44
Black	0.448	0.443	0.454	0.379	0.213
Male	0.556	0.551	0.546	0.554	0.565
Diabetic	0.538	0.542	0.546	0.555	0.569
Hypertensive	0.911	0.908	0.909	0.906	0.902
Incident Hemoglobin	9.664	9.710	9.737	9.819	9.935
Facility Characteristics					
Facility Elevation (ft)	29.2	144.3	434.4	713.6	1886.7
Independent Ownership	0.172	0.161	0.150	0.197	0.184
Resource Use					
Epo Dose (1000 IUs)	36.65	36.05	36.67	34.20	30.38
Receives Any EPO	0.759	0.761	0.751	0.708	0.662
Medicare Spending ($)					
Total	7,884	7,890	7,224	7,290	6,959
Inpatient	2,637	2,564	2,277	2,301	2,196
Dialysis	2,390	2,456	2,334	2,353	2,322
Part D	571	550	523	499	480
Outpatient	373	417	441	463	427
Health Outcomes					
Hemoglobin (g/dL)	10.79	10.81	10.82	10.83	10.89
Mortality	0.015	0.014	0.015	0.015	0.015
Hospitalizations					
Any Cause	0.1344	0.1305	0.1283	0.1348	0.1275
Cardiac Event	0.0257	0.0258	0.0246	0.0256	0.0227
Septicemia	0.0103	0.0100	0.0094	0.0099	0.0094
Transfusions					
Total	0.0326	0.0302	0.0296	0.0298	0.0288
Inpatient	0.0279	0.0257	0.0236	0.0234	0.0221
Outpatient	0.0053	0.0051	0.0067	0.0072	0.0075
Emergency Room	0.0001	0.0001	0.0001	0.0001	0.0001
Unique Patients	60,055	58,219	58,652	58,026	58,970
Patient-Months	543,541	528,788	531,440	518,537	527,525

Notes: An observation is a patient-month. Sample consists of observations from January to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Predicted mortality is the predicted value for each observation from a regression of mortality on patient controls and time fixed effects. Time fixed effects are not included in the prediction. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Facility Elevation is measured in feet above sea level. The cut points between elevation quintiles are 73, 260, 599, and 870 feet above sea level.

B. Anticipatory Effects

Given the difficulty in changing clinical practices, we may expect them to change gradually over time. That is, we might expect anticipatory effects of the bundle. Indeed, in Figures 1 and 4, among others, we see that EPO began to decrease in mid-2010, prior to the bundle's start in January 2011. In this appendix, we both quantify these anticipatory effects as well as show that our results are robust to changing the date of treatment to include this period of anticipatory action.

To identify and quantify anticipatory effects, we use the methods of Brot-Goldberg et al. (2017). First, we estimate

$$\bar{Y}_t = \beta_0 + \beta_1 t + X_t + \bar{\epsilon}_t, \tag{9}$$

where $\bar{Y}_t$ is the mean EPO dose in month t and X_t is a series of month fixed effects. We estimate this equation using only data through December 2009. We can then use the estimated coefficients to calculate the predicted level of EPO for each month in 2010 and 2011, $\widehat{\bar{Y}}_t$. We present these predicted values as well as the observed values in Table **??**. We see that the first month in which the realized mean EPO dose is below the predicted level by a statistically-significant amount is October 2010. We see that this drop continues to grow through 2011.

To identify further when facilities began to respond to the bundle, we use a falsification test from Baicker and Svoronos (2019). In particular, we construct a test statistic from a series of Wald tests, testing each month in our data as a potential structural break in the time series of mean monthly EPO doses. The month that returns the most statistically significant structural break is October 2010, with a Wald statistic of 269.

Our time series results are robust to using October 2010 as the start of the bundle, as are our IV and allocative efficiency results.

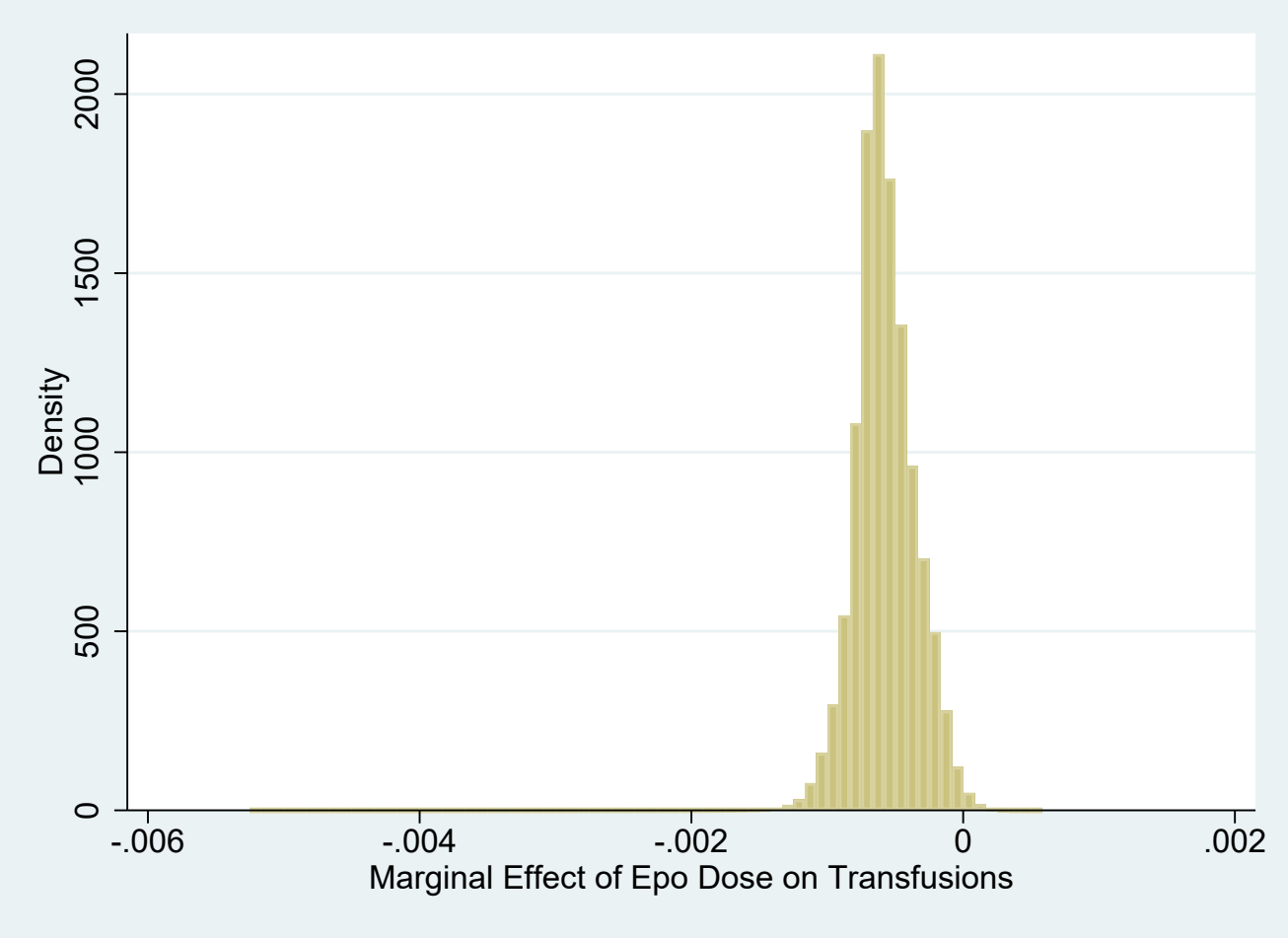
Table A4
Effect of Bundle on EPO Dose and Health Outcomes

	(1) EPO	(2) EPO	(3) EPO	(4) EPO
PPS	-19.19***	-20.82***	-17.91***	-5.035***
	(0.243)	(0.233)	(0.417)	(0.223)
Pat/Fac Controls	0	1	1	1
Facility FE	0	0	1	1
Patient FE	0	0	0	1
Dep. Var. Mean	46.82	46.82	46.82	46.86
R-squared	0.0240	0.0812	0.136	0.532
Observations	10157714	10157714	10157683	10139936

Notes: OLS estimates from equation (1). Dependent variable is total monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. PPS is an indicator variable for January 2011 or later. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively. Dependent variable in column (1) is hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (2)–(5) are binary outcome variables. PPS is an indicator variable for October 2010 or later. An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Figure A1

Histogram of Predicted Marginal Effects ($\widehat{\frac{\partial Y_{ijt}}{\partial E_{ijt}}}$) of EPO on Transfusions



Notes: Predicted values come from IV estimates of equation (6). An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects.

Table A5
Effect of Bundle on EPO Dose and Health Outcomes

	(1) HGB	(2) Transfusion	(3) Hosp., Any Cause	(4) Hosp., Cardiac Event	(5) Mortality
PPS	-0.442***	0.00499***	-0.00560***	-0.00211***	-0.000829***
	(0.00815)	(0.000208)	(0.000452)	(0.000187)	(0.000116)
Pat/Fac Controls	1	1	1	1	1
Facility FE	1	1	1	1	1
Dep. Var. Mean	11.08	0.0287	0.137	0.0267	0.0156
R-squared	0.0758	0.0118	0.0212	0.00775	0.00843
Observations	8304637	10157683	10157683	10157683	10157683

Notes: OLS estimates from equation (2). Dependent variable in column (1) is hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (2)–(5) are binary outcome variables. PPS is an indicator variable for October 2010 or later. An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table A6
Effect of Bundle on EPO Dose, Pre- and Post-Trends

	(1) EPO	(2) EPO	(3) EPO	(4) EPO
PPS	-4.796***	-5.848***	-5.886***	-5.247***
	(0.218)	(0.243)	(0.238)	(0.223)
Time Trend	-0.503***	-0.515***	-0.499***	-0.612***
	(0.0157)	(0.0156)	(0.0183)	(0.0532)
Post-PPS Trend Change	-0.207***	-0.236***	-0.228***	-0.270***
	(0.0224)	(0.0215)	(0.0212)	(0.0208)
Pat/Fac Controls	0	1	1	1
Facility FE	0	0	1	1
Patient FE	0	0	0	1
Dep. Var. Mean	46.82	46.82	46.82	46.86
R-squared	0.0287	0.0851	0.139	0.532
Observations	10157714	10157714	10157683	10139936

Notes: OLS estimates from equation (2). Dependent variable is total monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. PPS is an indicator variable for October 2010 or later. Time Trend is a continuous measure of months since October 2010. This means the value for October 2010 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table A7
Effect of Bundle on Other Outcomes, Pre- and Post-Trends

	(1) HGB	(2) Transfusion	(3) Hosp., Any Cause	(4) Hosp., Cardiac Event	(5) Mortality
PPS	-0.232***	0.00293***	-0.000163	-0.0000754	-0.000235
	(0.00701)	(0.000285)	(0.000576)	(0.000249)	(0.000177)
Time Trend	-0.0132***	0.000174***	-0.000185***	-0.0000871***	-0.0000319**
	(0.000342)	(0.0000155)	(0.0000340)	(0.0000144)	(0.00000988)
Post-PPS Trend Change	0.00543***	-0.000146***	-0.000188***	-0.0000331+	0.00000387
	(0.000518)	(0.0000211)	(0.0000434)	(0.0000177)	(0.0000119)
Pat/Fac Controls	1	1	1	1	1
Facility FE	1	1	1	1	1
Dep. Var. Mean	11.08	0.0287	0.137	0.0267	0.0156
R-squared	0.0781	0.0119	0.0212	0.00776	0.00843
Observations	8304637	10157683	10157683	10157683	10157683

Notes: OLS estimates from equation (2). Dependent variable in column (1) is hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (2)–(5) are binary outcome variables. PPS is an indicator variable for October 2010 or later. Time Trend is a continuous measure of months since October 2010. This means the value for October 2010 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table A8
The Effect of EPO on Health Outcomes

	HGB		Transfusion	
	(1) OLS	(2) IV	(3) OLS	(4) IV
EPO	-0.00287***	0.0165***	0.000127***	-0.000580***
	(0.0000252)	(0.00465)	(0.00000252)	(0.000149)
Year-Month FE	1	1	1	1
Pat/Fac Controls	1	1	1	1
Facility FE	1	1	1	1
Dep. Var. Mean	11.17	11.17	0.0279	0.0279
Observations	8056164	8056164	9979284	9979284
First-Stage F-statistic		37.28		54.89

Notes: OLS and IV estimates from equation (3). Dependent variable in columns (1)–(2) is hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (3)–(4) is a binary outcome variable for receiving a blood transfusion. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table A9
The Effect of EPO on Hospitalizations and Mortality

	Hosp., Any Cause		Hosp., Cardiac Event		Hosp., Septicemia		Mortality	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
EPO	0.000157***	0.0000821	0.0000160***	0.000123	-0.000000428	0.0000280	-0.000115***	0.000147*
	(0.00000351)	(0.000242)	(0.00000122)	(0.0000976)	(0.000000602)	(0.0000534)	(0.000000888)	(0.0000659)
Year-Month FE	1	1	1	1	1	1	1	1
Pat/Fac Controls	1	1	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1	1	1
Dep. Var. Mean	0.139	0.139	0.0274	0.0274	0.00930	0.00930	0.0159	0.0159
Observations	9979284	9979284	9979284	9979284	9979284	9979284	9979284	9979284
First-Stage F-statistic		54.89		54.89		54.89		54.89

Notes: OLS and IV estimates from equation (3). Dependent variables are binary outcomes. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table A10

PREDICTED MARGINAL EFFECTS ($\widehat{\frac{\partial Y_{ijt}}{\partial E_{ijt}}}$) SUMMARY STATISTICS

	Mean	Std. Dev.	Min	Max	N/n/T-bar
Overall	-0.0006	0.0002	-0.0053	0.0006	10,157,714
Between		0.0002	-0.0049	0.0006	463,547
Within		0.0001	-0.0022	0.0008	21.91

Notes: Predicted values come from IV estimates of equation (6). EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects.

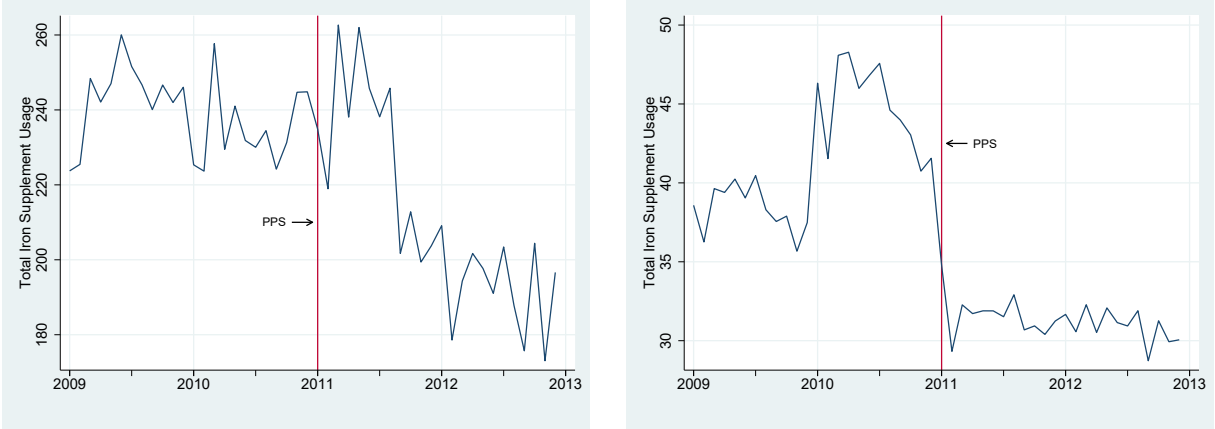
Table A11
Difference in EPO by the Responsiveness of Transfusions to EPO

	(1) EPO	(2) EPO	(3) Transfusion	(4) Transfusion
Estimated MFX Z-Score	-2.836***	-2.822***	-0.0149***	-0.0149***
	(0.178)	(0.178)	(0.000332)	(0.000332)
PPS	-5.704***		0.00312***	
	(0.238)		(0.000287)	
Estimated MFX Z-Score × PPS	1.009***	0.893***	0.00472***	0.00463***
	(0.104)	(0.103)	(0.000185)	(0.000186)
Time Trend	-0.649***		-0.0000746***	
	(0.0143)		(0.0000130)	
Pat/Fac Controls	1	1	1	1
Month FE and Trend	1	0	1	0
Year-Month FE	0	1	0	1
Facility FE	1	1	1	1
R-squared	0.139	0.140	0.0126	0.0126
Dep. Var. Mean	46.82	46.82	0.0287	0.0287
Observations	10157683	10157683	10157683	10157683

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Dependent variables in columns (3)–(4) is a binary measure of transfusions. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. Transfusion rate is the dependent variable of this regression. An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

C. Other Drugs

Figure A2
Use of Other Injectable Drugs



(a) Mean Monthly IV Iron Dose

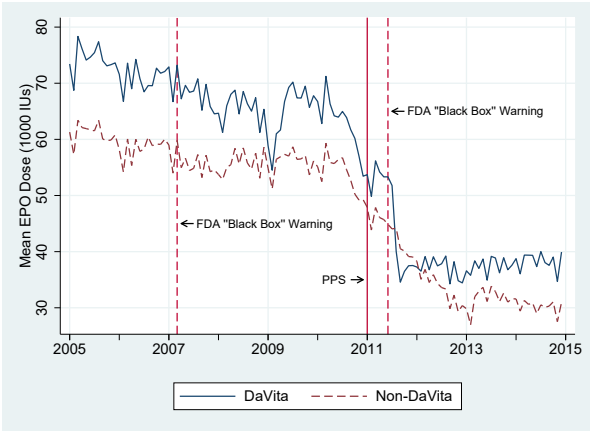
(b) Mean Monthly Vitamin D Dose

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. The solid vertical line indicates the official start date of PPS, January 2011.

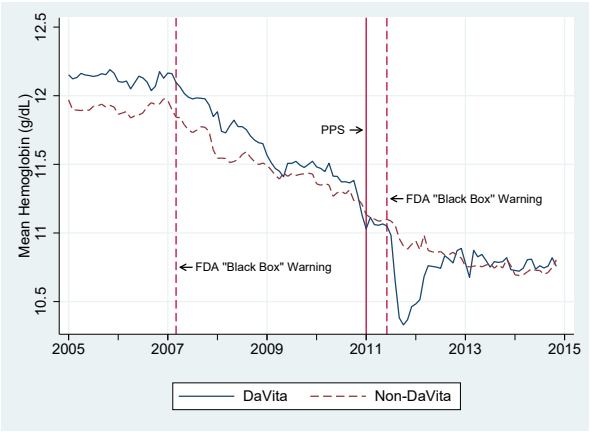
D. Differential EPO Response of One Large Chain

We notice a distinct drop in hemoglobin in mid-2011. This corresponds both to the second FDA "Black Box" warning as well as the renegotiation of one large chain's contract with Amgen, the monopoly supplier of EPO at the time. We see that the sharp drop in EPO and hemoglobin levels occurs only for this large chain's patients, indicating that the cause is likely their contract renegotiation rather than the "Black Box" warning.

Figure A3
Key Variables by Facility Ownership



(a) Monthly EPO Dose for One Large Chain and Other Facilities' Patients



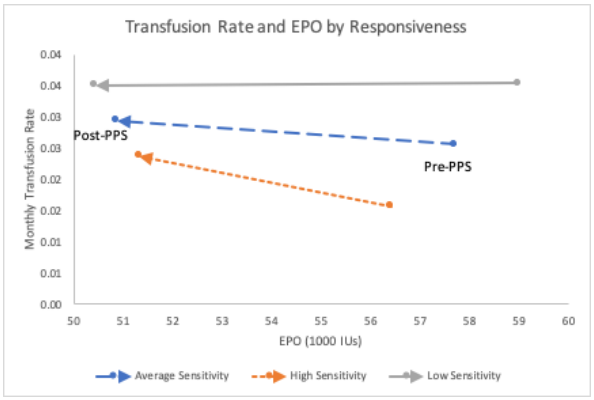
(b) Mean HGB for One Large Chain and Other Facilities' Patients

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. The solid vertical line indicates the official start date of PPS, January 2011. Vertical dashed lines indicate the release of official warnings from the FDA about the safety of high EPO doses.

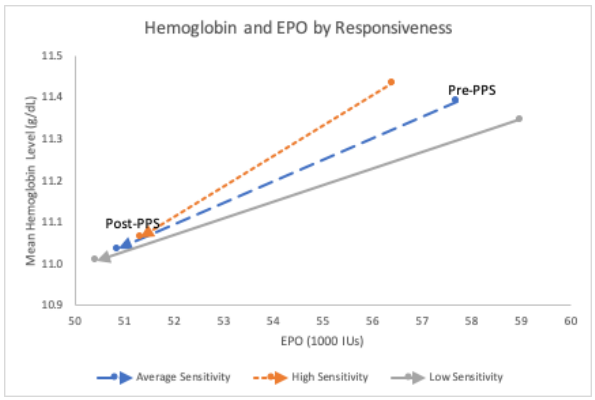
E. Supplemental Tables and Figures from Section 5

The following figures plot how outcomes and spending changed following the move to bundled payments. As EPO doses fell following the bundle, the figures should be read from right to left. The plots are constructed using the coefficients from Tables 12–14 for patients with low, average, and high responsiveness to EPO.

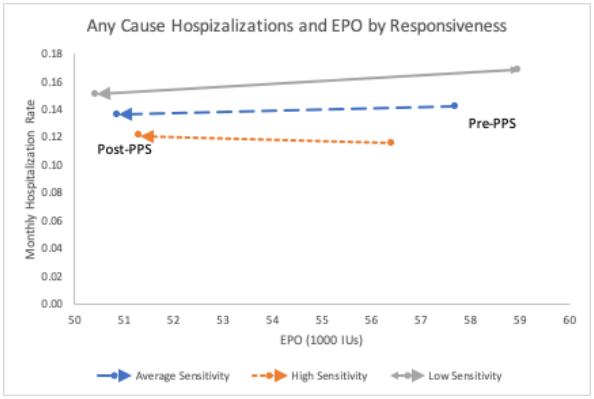
Figure A4
Responsiveness Quintile Changes Across the Bundle



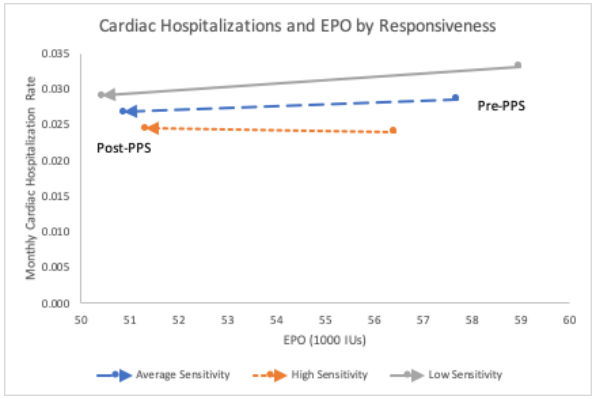
(a) Transfusion Rate



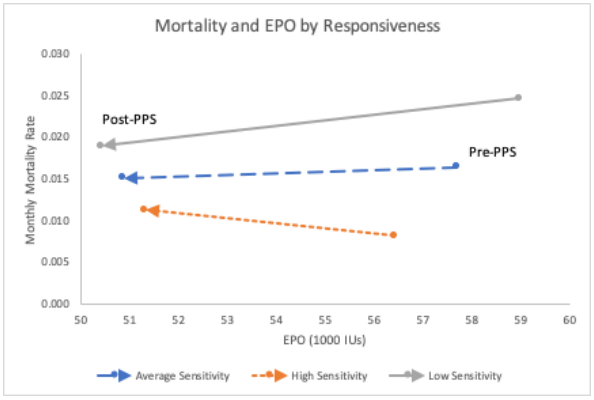
(b) Hemoglobin



(c) Hospitalization Rate



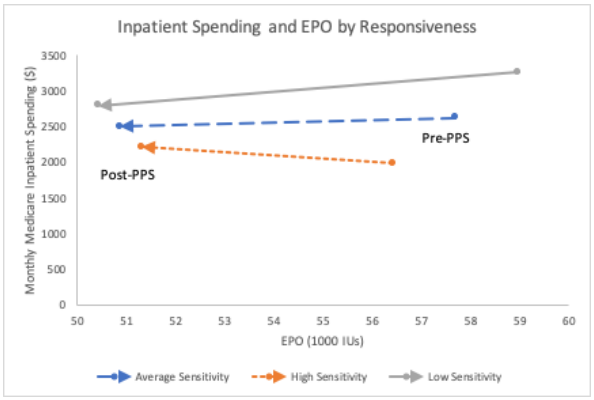
(d) Cardiac Hospitalization Rate



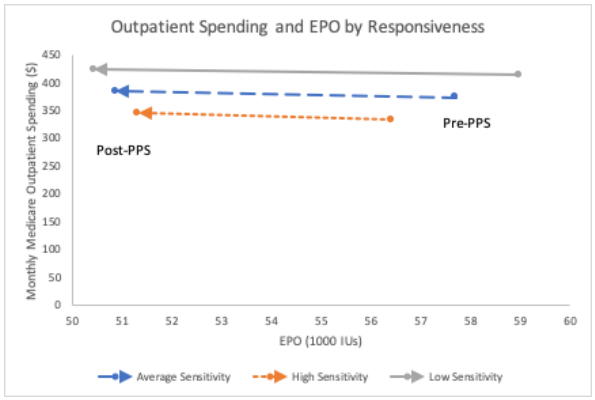
(e) Mortality Rate

Notes: "EPO-responsive" ("EPO-unresponsive") refers to patients with average estimated marginal effects of EPO on transfusions in the fifth (first) quintile. This corresponds to being at least 0.78 standard deviations below (0.73 standard deviations above) the average estimated marginal effect. Predicted values come from IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. The solid vertical line indicates the official start date of PPS, January 2011.

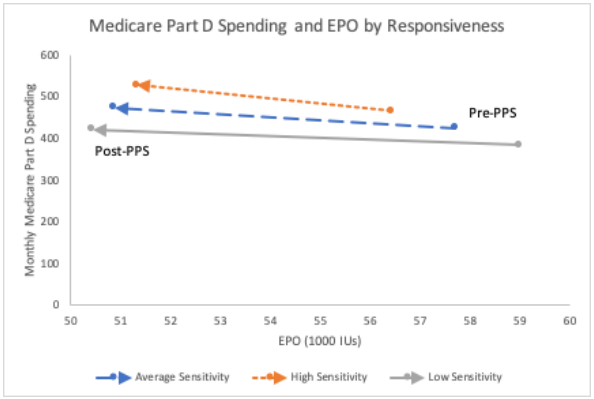
Figure A5
Responsiveness Quintile Changes Across the Bundle



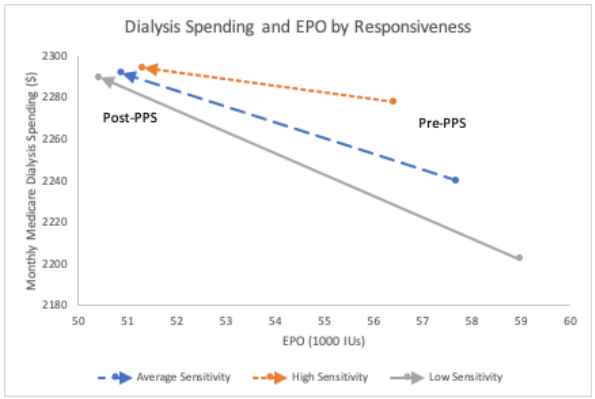
(a) Inpatient Spending



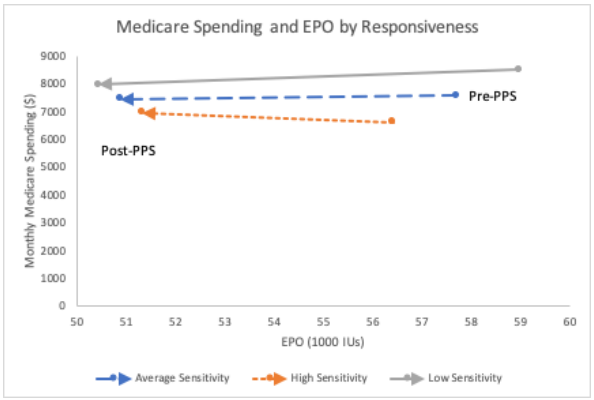
(b) Outpatient Spending



(c) Part D Spending



(d) Dialysis Spending



(e) Total Spending

Notes: "EPO-responsive" ("EPO-unresponsive") refers to patients with average estimated marginal effects of EPO on transfusions in the fifth (first) quintile. This corresponds to being at least 0.78 standard deviations below (0.73 standard deviations above) the average estimated marginal effect. Predicted values come from IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. The solid vertical line indicates the official start date of PPS, January 2011.

Table A12
Difference in EPO by the Responsiveness of Transfusion Rates to EPO, Quintiles

	(1) EPO	(2) EPO	(3) Transfusion	(4) Transfusion
Second Quintile of EPO-Responsiveness	-2.042***	-1.867***	-0.0256***	-0.0255***
	(0.318)	(0.318)	(0.000477)	(0.000477)
Third Quintile of EPO-Responsiveness	-2.883***	-2.472***	-0.0289***	-0.0289***
	(0.324)	(0.323)	(0.000479)	(0.000478)
Fourth Quintile of EPO-Responsiveness	-3.093***	-2.588***	-0.0299***	-0.0298***
	(0.319)	(0.318)	(0.000472)	(0.000471)
Fifth Quintile of EPO-Responsiveness	-3.905***	-3.380***	-0.0299***	-0.0298***
	(0.328)	(0.328)	(0.000483)	(0.000482)
PPS	-9.149***		-0.00776***	
	(0.362)		(0.000513)	
Second Quintile of EPO-Responsiveness × PPS	1.602***	1.011**	0.0127***	0.0126***
	(0.318)	(0.317)	(0.000529)	(0.000529)
Third Quintile of EPO-Responsiveness × PPS	3.588***	2.687***	0.0158***	0.0157***
	(0.319)	(0.316)	(0.000543)	(0.000544)
Fourth Quintile of EPO-Responsiveness × PPS	4.177***	3.151***	0.0162***	0.0160***
	(0.317)	(0.315)	(0.000532)	(0.000533)
Fifth Quintile of EPO-Responsiveness × PPS	5.513***	4.447***	0.0173***	0.0172***
	(0.329)	(0.327)	(0.000542)	(0.000543)
Time Trend	-0.518***		-0.0000865***	
	(0.0145)		(0.0000123)	
Patient Controls	0	0	0	0
Facility Controls	1	1	1	1
Month FE and Trend	1	0	1	0
Year-Month FE	0	1	0	1
Facility FE	1	1	1	1
R-squared	0.123	0.125	0.00945	0.00948
Dep. Var. Mean	48.27	48.27	0.0282	0.0282
Observations	10077264	10077264	10077264	10077264

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Dependent variables in columns (3)–(4) is a binary measure of transfusions. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table A13
Difference in Other Outcomes by the Responsiveness of Transfusion Rates to EPO, Quintiles

	HGB		Hosp., Any Cause		Hosp., Cardiac Event		Mortality	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Second Quintile of EPO-Responsiveness	0.145***	0.146***	-0.0708***	-0.0707***	-0.0133***	-0.0133***	-0.0240***	-0.0240***
	(0.00400)	(0.00400)	(0.00101)	(0.00101)	(0.000385)	(0.000385)	(0.000301)	(0.000301)
Third Quintile of EPO-Responsiveness	0.151***	0.152***	-0.0822***	-0.0821***	-0.0153***	-0.0153***	-0.0256***	-0.0256***
	(0.00404)	(0.00404)	(0.00101)	(0.00101)	(0.000370)	(0.000370)	(0.000311)	(0.000311)
Fourth Quintile of EPO-Responsiveness	0.143***	0.145***	-0.0829***	-0.0828***	-0.0151***	-0.0151***	-0.0251***	-0.0251***
	(0.00404)	(0.00403)	(0.00101)	(0.00101)	(0.000381)	(0.000381)	(0.000307)	(0.000308)
Fifth Quintile of EPO-Responsiveness	0.143***	0.145***	-0.0812***	-0.0810***	-0.0140***	-0.0140***	-0.0246***	-0.0246***
	(0.00423)	(0.00423)	(0.00105)	(0.00105)	(0.000381)	(0.000381)	(0.000310)	(0.000311)
PPS	-0.171***		-0.0339***		-0.00692***		-0.0130***	
	(0.00749)		(0.000984)		(0.000400)		(0.000332)	
Second Quintile of EPO-Responsiveness × PPS	-0.0660***	-0.0664***	0.0344***	0.0342***	0.00739***	0.00737***	0.0149***	0.0149***
	(0.00478)	(0.00478)	(0.00109)	(0.00109)	(0.000432)	(0.000433)	(0.000326)	(0.000328)
Third Quintile of EPO-Responsiveness × PPS	-0.0758***	-0.0778***	0.0448***	0.0445***	0.00884***	0.00881***	0.0164***	0.0165***
	(0.00496)	(0.00497)	(0.00110)	(0.00110)	(0.000425)	(0.000426)	(0.000330)	(0.000332)
Fourth Quintile of EPO-Responsiveness × PPS	-0.0667***	-0.0693***	0.0454***	0.0451***	0.00922***	0.00919***	0.0162***	0.0162***
	(0.00498)	(0.00498)	(0.00108)	(0.00108)	(0.000439)	(0.000441)	(0.000331)	(0.000334)
Fifth Quintile of EPO-Responsiveness × PPS	-0.0851***	-0.0879***	0.0473***	0.0470***	0.00922***	0.00918***	0.0167***	0.0167***
	(0.00553)	(0.00554)	(0.00110)	(0.00110)	(0.000435)	(0.000437)	(0.000335)	(0.000338)
Time Trend	-0.0102***		-0.000632***		-0.000169***		-0.000112***	
	(0.000328)		(0.0000259)		(0.0000113)		(0.00000805)	
Patient Controls	0	0	0	0	0	0	0	0
Facility Controls	1	1	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1	0	1
Facility FE	1	1	1	1	1	1	1	1
R-squared	0.0721	0.0756	0.0147	0.0147	0.00433	0.00434	0.00533	0.00533
Dep. Var. Mean	11.12	11.12	0.138	0.138	0.0271	0.0271	0.0157	0.0157
Observations	8181736	8181736	10077264	10077264	10077264	10077264	10077264	10077264

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (3)–(8) are binary measures. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table A14
Difference in Medicare Spending by the Responsiveness of Transfusion Rates to EPO, Quintiles

	Inpatient		Outpatient		Dialysis		Part D		Total	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Second Quintile of EPO-Responsiveness	-1693.9***	-1689.5***	-76.81***	-76.74***	146.3***	144.5***	77.74***	77.08***	-2392.8***	-2386.1***
	(26.77)	(26.75)	(3.083)	(3.082)	(4.252)	(4.252)	(3.435)	(3.434)	(36.36)	(36.35)
Third Quintile of EPO-Responsiveness	-1927.3***	-1917.6***	-105.7***	-105.6***	171.8***	168.2***	108.5***	107.0***	-2751.9***	-2737.1***
	(26.71)	(26.68)	(3.039)	(3.038)	(4.281)	(4.282)	(3.494)	(3.489)	(36.59)	(36.55)
Fourth Quintile of EPO-Responsiveness	-1955.2***	-1943.5***	-124.4***	-124.1***	172.0***	167.9***	117.4***	115.6***	-2818.3***	-2800.3***
	(26.41)	(26.37)	(3.050)	(3.047)	(4.271)	(4.274)	(3.543)	(3.539)	(36.21)	(36.16)
Fifth Quintile of EPO-Responsiveness	-1968.1***	-1956.0***	-125.8***	-125.6***	128.4***	124.2***	125.1***	123.2***	-2874.9***	-2856.2***
	(27.75)	(27.72)	(3.077)	(3.075)	(4.344)	(4.343)	(3.529)	(3.525)	(38.36)	(38.32)
PPS	-937.7***		-9.663**		131.2***		-13.61***		-1245.6***	
	(26.77)		(3.480)		(5.047)		(2.934)		(34.73)	
Second Quintile of EPO-Responsiveness × PPS	997.9***	983.5***	-8.062*	-8.459*	-145.1***	-140.3***	27.38***	29.49***	1262.5***	1239.8***
	(28.55)	(28.55)	(3.823)	(3.824)	(4.599)	(4.600)	(3.676)	(3.684)	(37.64)	(37.65)
Third Quintile of EPO-Responsiveness × PPS	1211.6***	1190.3***	2.778	2.310	-172.0***	-164.7***	34.99***	38.23***	1573.5***	1540.5***
	(29.20)	(29.22)	(3.736)	(3.741)	(4.538)	(4.543)	(3.750)	(3.754)	(38.89)	(38.90)
Fourth Quintile of EPO-Responsiveness × PPS	1226.7***	1202.8***	13.57***	13.06***	-164.8***	-156.8***	31.11***	34.77***	1596.1***	1558.9***
	(28.66)	(28.68)	(3.780)	(3.784)	(4.545)	(4.549)	(3.902)	(3.910)	(37.78)	(37.81)
Fifth Quintile of EPO-Responsiveness × PPS	1307.2***	1282.3***	17.52***	16.99***	-136.1***	-127.8***	21.68***	25.50***	1710.9***	1672.3***
	(29.21)	(29.25)	(3.903)	(3.914)	(4.743)	(4.748)	(3.783)	(3.786)	(38.64)	(38.70)
Time Trend	-12.43***		1.171***		3.942***		3.423***		-10.32***	
	(0.694)		(0.110)		(0.167)		(0.0825)		(0.926)	
Patient Controls	0	0	0	0	0	0	0	0	0	0
Facility Controls	1	1	1	1	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1	0	1	0	1
Facility FE	1	1	1	1	1	1	1	1	1	1
R-squared	0.0105	0.0105	0.0145	0.0146	0.0567	0.0589	0.0395	0.0398	0.0221	0.0223
Dep. Var. Mean	2557.5	2557.5	393.7	393.7	2286.8	2286.8	465.2	465.2	7555.4	7555.4
Observations	9771287	9771287	9771287	9771287	9771287	9771287	9771287	9771287	9771287	9771287

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (3)–(8) are binary measures. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table A15
Difference in Other Outcomes by Responsiveness of Transfusions to EPO and Chain Status

	HGB		Hosp., Any Cause		Hosp., Cardiac Event		Mortality	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Chain Ownership	0.0191	0.00193	0.00257	0.00322	0.00166*	0.00175*	-0.000307	0.0000181
	(0.0244)	(0.0214)	(0.00214)	(0.00206)	(0.000761)	(0.000706)	(0.000493)	(0.000446)
EPO-Responsiveness Z-Score	0.0445***	0.0442***	-0.0260***	-0.0260***	-0.00409***	-0.00416***	-0.00784***	-0.00787***
	(0.00349)	(0.00364)	(0.000743)	(0.000728)	(0.000241)	(0.000236)	(0.000253)	(0.000248)
EPO-Responsiveness Z-Score × Chain	0.000445	0.00144	-0.000526	-0.000378	-0.000614*	-0.000528+	-0.000532+	-0.000499+
	(0.00378)	(0.00401)	(0.000837)	(0.000817)	(0.000278)	(0.000271)	(0.000279)	(0.000272)
PPS	-0.207***		0.000750		0.000385		-0.000356	
	(0.0212)		(0.00115)		(0.000508)		(0.000383)	
PPS × Chain	-0.0306		0.000379		-0.000342		0.000469	
	(0.0221)		(0.00127)		(0.000557)		(0.000414)	
EPO-Responsiveness Z-Score × PPS	-0.0106*	-0.0109*	0.0115***	0.0113***	0.00185***	0.00185***	0.00390***	0.00390***
	(0.00501)	(0.00493)	(0.000746)	(0.000743)	(0.000294)	(0.000293)	(0.000235)	(0.000234)
EPO-Responsiveness Z-Score × PPS × Chain	-0.00858	-0.00903+	-0.000160	-0.000190	0.000573+	0.000553+	0.000662*	0.000660*
	(0.00534)	(0.00526)	(0.000848)	(0.000844)	(0.000334)	(0.000333)	(0.000265)	(0.000263)
Time Trend	-0.0108***		-0.000533***		-0.000139***		-0.0000841***	
	(0.000835)		(0.0000478)		(0.0000205)		(0.0000157)	
Time Trend × Chain	0.000633		-0.0000846+		-0.0000294		-0.0000309+	
	(0.000811)		(0.0000513)		(0.0000217)		(0.0000162)	
Patient Controls	0	0	0	0	0	0	0	0
Facility Controls	1	1	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1	0	1
Facility FE	1	1	1	1	1	1	1	1
R-squared	0.0718	0.0752	0.0139	0.0139	0.00417	0.00418	0.00486	0.00486
Dep. Var. Mean	11.12	11.12	0.138	0.138	0.0271	0.0271	0.0157	0.0157
Observations	8181736	8181736	10077264	10077264	10077264	10077264	10077264	10077264

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Dependent variables in columns (3)–(4) is a binary measure of transfusions. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. Transfusion rate is the dependent variable of this regression. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table A16
Difference in Medicare Spending by Responsiveness of Transfusions to EPO and Chain Status

	Inpatient		Outpatient		Dialysis		Part D		Total	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Chain Ownership	63.29	43.97	3.742	4.061	24.55	-13.75	36.99***	27.30**	191.9**	97.74
	(46.07)	(41.98)	(8.912)	(8.490)	(22.09)	(21.40)	(8.610)	(8.308)	(70.92)	(65.37)
EPO-Responsiveness Z-Score	-673.5***	-668.5***	-40.63***	-40.75***	44.27***	38.76***	37.97***	38.56***	-998.7***	-997.1***
	(22.12)	(21.64)	(2.121)	(2.101)	(3.239)	(3.381)	(2.663)	(2.634)	(29.70)	(28.92)
EPO-Responsiveness Z-Score × Chain	45.10+	43.90+	0.0838	0.322	-8.172*	-2.970	2.980	1.533	75.23*	81.07*
	(24.18)	(23.56)	(2.375)	(2.349)	(3.668)	(3.809)	(2.975)	(2.933)	(32.59)	(31.64)
PPS	55.25		-3.191		94.67***		18.51***		191.8***	
	(35.05)		(4.667)		(8.624)		(3.573)		(45.65)	
PPS × Chain	-35.69		-1.385		-111.2***		-10.65**		-233.6***	
	(37.79)		(5.029)		(9.484)		(3.816)		(48.95)	
EPO-Responsiveness Z-Score × PPS	334.0***	325.3***	-0.0388	-0.180	-32.73***	-28.08***	15.82***	16.79***	422.0***	411.5***
	(22.07)	(21.99)	(2.898)	(2.892)	(3.375)	(3.524)	(2.811)	(2.826)	(28.79)	(28.58)
EPO-Responsiveness Z-Score × PPS × Chain	12.98	12.85	1.838	1.741	-3.304	-5.549	-3.992	-3.697	16.86	12.98
	(24.38)	(24.25)	(3.344)	(3.338)	(3.882)	(4.004)	(3.175)	(3.190)	(31.90)	(31.63)
Time Trend	-13.08***		1.330***		2.892***		2.436***		-13.23***	
	(1.384)		(0.213)		(0.303)		(0.164)		(1.856)	
Time Trend × Chain	1.466		-0.0708		1.337***		1.044***		4.642*	
	(1.438)		(0.216)		(0.309)		(0.173)		(1.920)	
Patient Controls	0	0	0	0	0	0	0	0	0	0
Facility Controls	1	1	1	1	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1	0	1	0	1
Facility FE	1	1	1	1	1	1	1	1	1	1
R-squared	0.00996	0.0100	0.0143	0.0144	0.0559	0.0579	0.0388	0.0390	0.0215	0.0217
Dep. Var. Mean	2557.5	2557.5	393.7	393.7	2286.8	2286.8	465.2	465.2	7555.4	7555.4
Observations	9771287	9771287	9771287	9771287	9771287	9771287	9771287	9771287	9771287	9771287

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Dependent variables in columns (3)–(4) is a binary measure of transfusions. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. Transfusion rate is the dependent variable of this regression. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. +, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

F. Allocative Efficiency of Improving HGB Levels

In this section we repeat this exercise estimating equation 6 using patients' end-of-month HGB levels as the dependent variable. HGB is a direct measure of anemia severity and a key component of the mechanism through which EPO affects patient outcomes, including the need for blood transfusions. We then construct each patient's EPO-responsiveness Z-score in a similar manner, the one difference being that we do not multiply by negative one as the distribution of marginal effects of EPO on HGB is already positive.

It is natural to expect individuals who are responsive to EPO in the sense that it increases their HGB to be the same individuals for whom EPO decreases the likelihood that they need a transfusion, but this need not be true. We find that the correlation between these two notions of responsiveness is 0.2641. Appendix Table A17 gives the number of patient-month observations in the quintiles of the estimated marginal effect of EPO on hemoglobin and transfusion rate. It generally shows that patients in the low (high) end of the distribution of HGB responsiveness to EPO are found in the low (high) end of transfusion responsiveness to HGB.

Figure A7 breaks out time trends in EPO use and HGB levels by EPO-responsiveness type with respect to HGB levels. The figure shows that for EPO-unresponsive patients doses fell relatively more than for EPO-responsive patients, similar to what we saw with the marginal effects on transfusions. Panel b shows this it driven at least in part by the extensive margin with patients who are nonresponsive to EPO getting taken off the drug altogether, suggesting a reduction in waste. Looking at trends in HGB levels in Figure A8 we see an overall decrease in HGB levels but this decrease in greater for EPO responsive patients—those who see the smallest drop in their EPO doses.

In January 2012, the reporting requirements for hemoglobin levels changed. Prior to this date, hemoglobin only had to be reported on claims for reimbursement of EPO; after, all claims were required to report hemoglobin. This means that prior to 2012, we only observe hemoglobin levels for those patients that also receive a positive EPO dose. In order to assuage worries that the differential change in EPO we estimate for patients based on the responsiveness of their HGB to EPO doses is driven by this reporting change. We recreate Figure A8 using only those observations for which EPO dose is strictly positive. This means that we restrict our attention to only those observations for which EPO was required to be reported both before and after the reporting requirements change. We see in Figure A9 that while the differences between EPO-responsive and EPO-unresponsive patients are more muted, we nonetheless see the same pattern.

Results from estimating equation 8 are displayed in Table A20 and echo the results using transfusion responsiveness to EPO. Prior to the bundle EPO-responsive patients received lower doses than unresponsive ones. This is in-line with the incentive structure of the pre-2011 era—providers seeking to maximize profits while respecting clinical standards. As discussed in Section 2 clinical guidelines of the time directed providers to avoid treating patients with HGB levels over 12 g/dL. EPO-unresponsive patients provided an opportunity to increase revenues through large EPO doses with little risk of HGB levels exceeding this threshold. The results in column (1) indicate that a patient with an estimated marginal effect of EPO on hemoglobin one standard deviation below average received XXX more EPO than an observably similar patient with average EPO-responsiveness. While the level of EPO decreased for all types of patients, the difference between EPO-responsive and EPO-unresponsive patients shrunk, indicating that EPO decreased more for the EPO-unresponsive. We also see that the EPO-responsive had higher levels of hemoglobin than the EPO-unresponsive prior to the bundle. After the bundle, the hemoglobin of both types of patients decreased, but more so for the EPO-unresponsive types, suggesting a reallocation from low-return to higher-return patients.

Table A17
Crosstabulation of EPO-Responsiveness with Respect to EPO and to Transfusion Rates

	EPO Sensitivity of Transfusions, Quintiles					
EPO Sensitivity of HGB	First	Second	Third	Fourth	Fifth	Total
First Quintile	498,053	493,162	423,011	340,668	260,591	2,015,485
Second Quintile	494,449	437,545	424,188	367,088	292,171	2,015,441
Third Quintile	416,823	412,358	424,942	429,506	331,822	2,015,451
Fourth Quintile	373,208	384,623	411,057	442,250	404,363	2,015,501
Fifth Quintile	232,928	287,790	332,279	435,937	726,477	2,015,411
Total	2,015,461	2,015,478	2,015,477	2,015,449	2,015,424	10,077,289

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Quintiles along the vertical axis were determined by within-patient average estimated marginal effect of EPO on hemoglobin from IV estimates of 6. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Quintiles along the horizontal axis were similarly determined with a binary measure of transfusion as the dependent variable of $\text{refeq}_p rodfunc$.

Table A18
Predicted Marginal Effects ($\widehat{\frac{\partial Y_{ijt}}{\partial E_{ijt}}}$) Summary Statistics

	Mean	Std. Dev.	Min	Max	N/n/T-bar
Overall	0.0163	0.0056	-0.0088	0.0634	10,077,289
Between		0.0055	-0.0079	0.0500	461,477
Within		0.0009	0.0034	0.0318	21.84

Notes: Predicted values come from IV estimates of equation (6). EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects.

Table A19

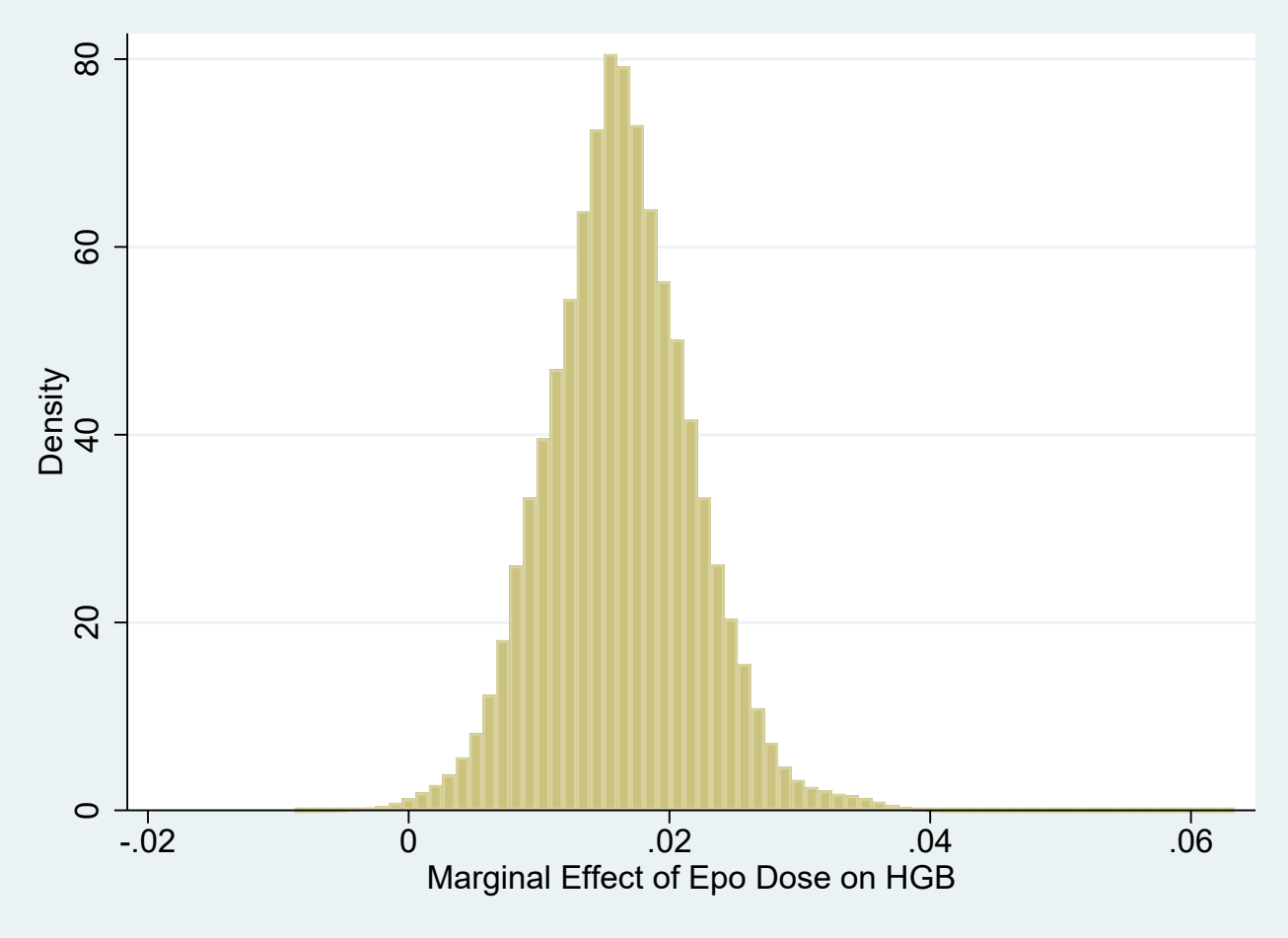
Patient Descriptive Statistics by the Responsiveness of Hemoglobin to EPO

	EPO Sensitivity Quintile				
	First	Second	Third	Fourth	Fifth
Patient Characteristics					
Predicted Mortality	0.012	0.014	0.014	0.018	0.020
Age (Years)	54.71	58.77	61.52	67.98	72.63
Months with ESRD	58.55	44.68	37.93	36.10	34.20
Black	0.401	0.377	0.413	0.367	0.355
Male	0.879	0.703	0.610	0.452	0.170
Diabetic	0.444	0.511	0.541	0.558	0.573
Hypertensive	0.930	0.914	0.903	0.893	0.890
Incident Hemoglobin	10.500	9.895	9.741	9.768	9.768
Inputs					
Facility Elevation (ft)	669.9	663.6	644.7	635.4	585.1
Epo Dose (1000 IUs)	59.66	60.68	60.09	57.98	55.59
Receives Any EPO	0.718	0.752	0.774	0.789	0.813
Health Outcomes					
Hemoglobin (g/dL)	11.45	11.44	11.45	11.45	11.46
Mortality	0.014	0.016	0.016	0.018	0.019
Hospitalizations					
Any Cause	0.1343	0.1433	0.1459	0.1457	0.1460
Cardiac Event	0.0254	0.0272	0.0290	0.0306	0.0331
Septicemia	0.0077	0.0083	0.0084	0.0090	0.0089
Transfusions					
Total	0.0213	0.0247	0.0258	0.0267	0.0263
Inpatient	0.0169	0.0200	0.0210	0.0219	0.0221
Outpatient	0.0049	0.0053	0.0054	0.0054	0.0047
Emergency Room	0.0001	0.0001	0.0001	0.0001	0.0001
Medicare Spending ($)					
Total	7,381	7,572	7,509	7,494	7,463
Inpatient	2,540	2,690	2,649	2,598	2,527
Dialysis	2,384	2,285	2,228	2,190	2,138
Part D	487	444	412	370	378
Outpatient	365	376	368	365	349
Unique Patients	96,655	97,623	90,764	89,859	86,576
Patient-Months	444,269	441,125	459,997	490,934	514,117

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Predicted mortality is the predicted value for each observation from a regression of mortality on patient controls and time fixed effects. Time fixed effects are not included in the prediction. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Facility Elevation is measured in feet above sea level. Predicted values come from IV estimates of equation (6).

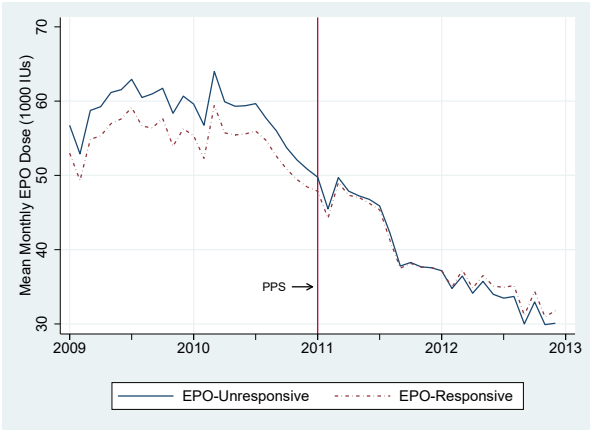
Figure A6

Histogram of Predicted Marginal Effects ($\widehat{\frac{\partial Y_{ijt}}{\partial E_{ijt}}}$) of EPO on Hemoglobin

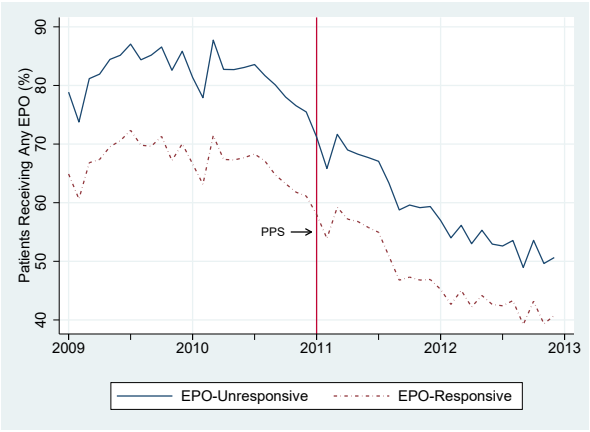


Notes: Predicted values come from IV estimates of equation (6). An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Facility controls include facility elevation, whether the facility to freestanding or hospital-based, and chain ownership status, as well as facility fixed effects. Further controls include month fixed effects.

Figure A7
Key Variables Over Time by Responsiveness of Hemoglobin to EPO



(a) Monthly EPO Dose Over Time by EPO Responsiveness



(b) Monthly EPO Dose Over Time by EPO Responsiveness Among Those Receiving EPO

(c) Share of Patients Receiving Any EPO Over Time by EPO Responsiveness

(d) Hemoglobin Over Time by EPO Responsiveness

Notes: "EPO-responsive" ("EPO-unresponsive") refers to patients with average estimated marginal effects of EPO on hemoglobin in the fifth (first) quintile. This corresponds to being at least 0.79 standard deviations above (0.81 standard deviations below) the average estimated marginal effect. Predicted values come from IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. The solid vertical line indicates the official start date of PPS, January 2011.

Figure A8
Hemoglobin Levels Over Time by EPO Responsiveness

Notes: "EPO-responsive" ("EPO-unresponsive") refers to patients with average estimated marginal effects of EPO on hemoglobin in the fifth (first) quintile. This corresponds to being at least 0.79 standard deviations above (0.81 standard deviations below) the average estimated marginal effect. Predicted values come from IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. The solid vertical line indicates the official start date of PPS, January 2011.

Figure A9
Hemoglobin Levels Over Time by EPO Responsiveness

Notes: "EPO-responsive" ("EPO-unresponsive") refers to patients with average estimated marginal effects of EPO on hemoglobin in the fifth (first) quintile. This corresponds to being at least 0.79 standard deviations above (0.81 standard deviations below) the average estimated marginal effect. Predicted values come from IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. The solid vertical line indicates the official start date of PPS, January 2011.

Table A20
Difference in EPO by the Responsiveness of Hemoglobin to EPO

	(1) EPO	(2) EPO	(3) HGB	(4) HGB
EPO-Responsiveness Z-Score	-1.408***	-1.364***	0.00376**	0.00397**
	(0.102)	(0.102)	(0.00125)	(0.00126)
PPS	-6.144***		-0.224***	
	(0.272)		(0.00652)	
EPO-Responsiveness Z-Score × PPS	1.602***	1.495***	-0.0786***	-0.0782***
	(0.0989)	(0.0989)	(0.00184)	(0.00185)
Time Trend	-0.516***		-0.0110***	
	(0.0145)		(0.000329)	
Patient Controls	0	0	0	0
Facility Controls	1	1	1	1
Month FE and Trend	1	0	1	0
Year-Month FE	0	1	0	1
Facility FE	1	1	1	1
R-squared	0.123	0.125	0.0729	0.0763
Dep. Var. Mean	48.27	48.27	11.12	11.12
Observations	10077264	10077264	8181736	8181736

Notes: OLS estimates from 8. Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Dependent variables in columns (3)–(4) is a binary measure of transfusions. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table A21
Difference in Other Outcomes by the Responsiveness of Hemoglobin to EPO

	Transfusion		Hosp., Any Cause		Hosp., Cardiac Event		Mortality	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPO-Responsiveness Z-Score	0.00148***	0.00149***	0.00290***	0.00292***	0.00240***	0.00240***	0.00162***	0.00162***
	(0.000107)	(0.000107)	(0.000294)	(0.000294)	(0.000108)	(0.000108)	(0.0000615)	(0.0000615)
PPS	0.00482***		0.00107+		0.000127		0.0000508	
	(0.000291)		(0.000589)		(0.000249)		(0.000182)	
EPO-Responsiveness Z-Score × PPS	0.000387**	0.000371**	-0.000439	-0.000479	-0.000273*	-0.000278*	0.000245**	0.000243**
	(0.000136)	(0.000136)	(0.000307)	(0.000307)	(0.000125)	(0.000125)	(0.0000791)	(0.0000790)
Time Trend	0.0000113		-0.000370***		-0.000119***		-0.0000389***	
	(0.0000122)		(0.0000259)		(0.0000112)		(0.00000801)	
Patient Controls	0	0	0	0	0	0	0	0
Facility Controls	1	1	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1	0	1
Facility FE	1	1	1	1	1	1	1	1
R-squared	0.00721	0.00724	0.0106	0.0106	0.00393	0.00393	0.00276	0.00277
Dep. Var. Mean	0.0282	0.0282	0.138	0.138	0.0271	0.0271	0.0157	0.0157
Observations	10077264	10077264	10077264	10077264	10077264	10077264	10077264	10077264

Notes: OLS estimates from 8. Dependent variable in columns (1)–(2) is monthly hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. Dependent variables in columns (3)–(8) are binary measures. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.

Table A22
Difference in EPO by the Responsiveness of Hemoglobin to EPO and Chain Status

	(1) EPO	(2) EPO	(3) HGB	(4) HGB
Chain Ownership	10.30***	10.98***	0.0171	0.000579
	(1.764)	(1.768)	(0.0244)	(0.0215)
EPO-Responsiveness Z-Score	-0.917***	-1.082***	0.00301	0.00266
	(0.186)	(0.181)	(0.00346)	(0.00352)
EPO-Responsiveness Z-Score × Chain	-0.617**	-0.361+	0.000966	0.00164
	(0.220)	(0.216)	(0.00369)	(0.00377)
PPS	-2.699***		-0.201***	
	(0.715)		(0.0213)	
PPS × Chain	-4.265***		-0.0298	
	(0.748)		(0.0222)	
EPO-Responsiveness Z-Score × PPS	0.350	0.322	-0.0608***	-0.0600***
	(0.235)	(0.227)	(0.00513)	(0.00520)
EPO-Responsiveness Z-Score × PPS × Chain	1.535***	1.454***	-0.0216***	-0.0222***
	(0.259)	(0.253)	(0.00547)	(0.00553)
Time Trend	-0.288***		-0.0114***	
	(0.0252)		(0.000835)	
Time Trend × Chain	-0.280***		0.000590	
	(0.0239)		(0.000809)	
Patient Controls	0	0	0	0
Facility Controls	1	1	1	1
Month FE and Trend	1	0	1	0
Year-Month FE	0	1	0	1
Facility FE	1	1	1	1
R-squared	0.124	0.125	0.0729	0.0763
Dep. Var. Mean	48.27	48.27	11.12	11.12
Observations	10077264	10077264	8181736	8181736

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are winsorized at the 99th percentile and measured in thousands of IUs. Dependent variables in columns (3)–(4) is a binary measure of transfusions. PPS is an indicator variable for January 2011 or later. Time Trend is a continuous measure of months since January 2011. This means the value for January 2011 is zero, while it is positive for subsequent months and negative for prior months. Post-PPS Trend Change is the interaction of PPS and Time Trend. Estimated MFX Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of 6. Transfusion rate is the dependent variable of this regression. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Patient controls include dummy variables for comorbidities from medical evidence forms, patient demographics, age, and dialysis tenure. Further controls include month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% level, respectively.