The Effect of Bundled Payments on Provider Behavior and Patient Outcomes: Evidence from the Dialysis Industry *

Paul J. Eliason[†], Benjamin Heebsh,[‡] Riley J. League[§],
Ryan C. McDevitt,[¶] James W. Roberts[‖]

November 11, 2021

We consider how health care providers respond to changes in the composition of bundled payments. After Medicare switched from fee-for-service reimbursements to a bundle, dialysis facilities halved their use of injectable anemia drugs. We identify the causal effects of this change using a novel source of variation — patients at higher elevations naturally require lower doses of anemia drugs — and show the reduction caused mortality to decline but transfusions to rise. Providers reduced costs by allowing spillovers to treatments outside the bundle and increased allocative efficiency by cutting doses more for patients who receive little benefit from the drug.

JEL Codes: D43, I11, I18, L10

*We thank nephrologists Matthew Ellis, Ruediger Lehrich, John Middleton, and Myles Wolf for providing valuable industry and medical 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.

[†]Department of Economics, Brigham Young University, paul.eliason@byu.edu

[‡]Federal Trade Commission, bheebsh.research@gmail.com. The research in this article was conducted while the author was a graduate student at Duke University. The views expressed in this article are those of the authors and do not represent the view of the Federal Trade Commission (FTC) or its commissioners.

[§]Department of Economics, Duke University, riley.league@duke.edu

[¶]Duke University, ryan.mcdevitt@duke.edu

[‖]Department of Economics, Duke University and NBER, j.roberts@duke.edu

1. Introduction

Health insurers use bundled payments to restrain reimbursement costs (Shatto, 2016). Compared to fee-for-service reimbursements that give providers a separate payment for each treatment or service, a bundled payment covers multiple aspects of care with a single reimbursement. Among the different forms of bundled payments, accountable care organizations lie at one extreme, with all providers who care for a patient splitting a single, comprehensive payment. Other types of bundles are less comprehensive, such as prospective payment systems that include only some essential services in the reimbursement. Proponents of these so-called alternative payment models contend that, because reimbursements do not depend on the actual costs incurred during treatment, they facilitate coordination and reduce unnecessary expenses. Counteracting these possible advantages is the incentive to undertreat patients: additional care does not yield any additional reimbursement, so some providers stand to gain by cutting costs in ways that may create spillovers for others. Given these inherent tradeoffs, we consider the precise ways in which providers reallocated resources in response to Medicare's move to a more-comprehensive bundled payment for dialysis, focusing specifically on the reallocation's effect on patients' health and the costs for other parts of the 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 end-stage renal disease (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 at one time Medicare's largest prescription drug expense, 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 mo-

tion 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 sessions under a new, more-comprehensive ESRD Prospective Payment System (herein referred to as the "bundle" or "PPS"), effectively turning each dose of EPO and other injectable drugs into a marginal cost rather than an incremental profit. Second, to address concerns that providers might respond to the bundle's financial incentives by cutting essential treatments, Medicare implemented the Quality Incentive Program (QIP) in 2012, allowing Medicare to reduce payments to facilities that fall below certain quality thresholds.

The move to include EPO in the bundle corresponded to a 49.4% drop in the average dose given to patients each month from its peak during the fee-for-service era. Although cutting doses of EPO, as well as the doses of other injectable drugs included in the payment reform, constitutes an unambiguous reduction in the amount of resources used to treat dialysis patients, the implications for patient welfare are less clear-cut: lower doses could benefit those who were being overtreated prior to the reform but could harm patients whose anemia is now undertreated. Determining whether these lower doses represent a decline in waste or a decrease in beneficial treatments is complicated by the fact that providers base their treatment decisions in part on a patient's underlying health, making any correlation between drug doses and outcomes potentially biased by unobserved confounds. Reflecting this possibility, we show that OLS regressions of hemoglobin (HGB) and blood transfusions on patients' EPO doses produce spurious negative and positive correlations, respectively, even though clinical trials have shown that the drug in fact causes the opposite response (Eschbach et al., 1989).

To overcome the empirical challenges associated with patients' unobserved health conditions and coincidental changes in dialysis care, we use a novel source of exogenous variation in providers' treatment decisions to identify the marginal effect of EPO on outcomes: patients at higher elevations have less severe anemia at baseline and are naturally more responsive to EPO (Winkelmayer et al., 2009; Brookhart et al., 2011). During the fee-for-service era, this physiological distinction made patients at higher elevations less profitable for providers, as clinical guidelines recommend they receive smaller doses of EPO. After the bundle, the financial incentives flipped, with patients at low elevations becoming less lucrative for providers since they no longer receive separate reimbursements corresponding to their comparatively larger doses. As a result, the uniformly applied payment reform effectively had different financial implications for facilities at different elevations.

Although promising as a source of exogenous variation, elevation likely would not be a valid instru-

ment 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. By instrumenting for EPO doses with the interaction term, our empirical strategy resembles a difference-in-differences estimation, with the first difference comparing EPO doses at high elevation facilities with those at lower elevations, while the second difference compares doses during the fee-for-service era when financial incentives favored higher doses relative to the bundle era when the financial incentives reversed.

From our first-stage estimates, we find that facilities at lower elevations both use more EPO and disproportionately reduced their doses after the bundle. The second stage then links the change in EPO to its effect on outcomes. 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, conditional on other controls, and several pieces of evidence suggest that our setting satisfies this requirement, such as parallel pre-trends for patients' EPO doses across high and low elevations.

We find that the payment reform had a large effect on providers' treatment decisions and, consequently, patients' outcomes. In our most-conservative specification that includes patient fixed effects, the average post-bundle drop in EPO of 9.6% caused a 3.5% decrease in hospitalizations from cardiac events and a 4.2% fall in mortality rates. Counteracting these benefits, however, was a 13.0% increase in the number of blood transfusions required by patients each month, a reflection of worse anemia management. This rise in transfusions highlights an important consequence of Medicare's decision to exclude some essential treatments from the bundle, as providers earn higher profits by managing patients' anemia with less EPO and more transfusions given that they bear the costs of the former but not the latter.

We extend our analysis to evaluate the change in allocative efficiency following the bundle, a key contribution to the literature on alternative payment models. We find that the cuts in EPO doses were not applied uniformly across all patients: doses for patients who benefit the most from EPO fell 17.9% compared to a drop of 26.1% for those who benefit the least. As a result, the bundle led to both a reduction in overall treatment intensity as well as a reallocation from low-benefit to high-benefit patients. Moreover, outcomes actually improved for low-benefit patients due to their much smaller doses

of EPO: hospitalizations for cardiac events, a primary complication of excessive EPO doses, dropped 21.6%, while trends in transfusion rates, a reflection of insufficient EPO, remained constant. Because health outcomes *improved* for these patients while overall Medicare spending *declined*, we interpret this as an increase in allocative efficiency. Partially offsetting these gains, however, is the slight increase in transfusion and mortality rates for the patients who benefit the most from EPO, as they fare worse after their doses fall following the bundle. Finally, we show that the large for-profit dialysis chains accounted for the bulk of the reallocation.

Our results contribute to a recent literature examining the effects of Medicare's alternative payment models, where a primary decision is the level at which to aggregate payments. Although narrow, episode-based bundles may be easier for individual physicians and small group practices to manage (Cutler and Ghosh, 2012), they may have a limited scope for reducing unnecessary care and promoting coordination among providers, making them susceptible to spillovers outside the bundle. Broader aggregation, such as with an accountable care organization (ACO), may be better for facilitating coordination but is more costly to implement (McWilliams et al., 2020; French et al., 2015; Nyweide et al., 2015).

As one prominent example of Medicare's move to alternative payment models, the Bundled Payments for Care Improvement Initiative was introduced in 2011 with the goal of restraining health care costs by paying providers a bundled rate for specific episodes of care rather than traditional fee-for-service reimbursements (Agarwal et al., 2020; Rolnick et al., 2020). Using observational data, Maughan et al. (2019) find that hospitals participating in the initiative had worse outcomes for average patients than similar non-participating hospitals did, but not for the most vulnerable patients. Martin et al. (2018) show similar results for lumbar fusions, where patients treated at participating hospitals had higher rates of readmission and repeat surgery. Others, by contrast, have found lower costs for lower extremity joint replacements, with no meaningful difference in quality (Dummit et al., 2016; Navathe et al., 2017; Barnett et al., 2019). These findings may be biased, however, as those that selectively opt in to alternative payment schemes may be particularly well suited to achieve savings. Because we use exogenous variation to study the effects of a mandatory bundle that had nonuniform financial incentives for providers, our novel research design allows us contribute to a literature that has so far primarily used observational data from a small number of hospitals that participated voluntarily in bundled payments.

One important exception to the observational studies of bundled payment models 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 readmissions or emergency room outcomes. Following this initial study, Einav et al. (2020b) show that the bundled payment program, which was originally implemented as a five-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 their behavior and for hospitals that had large changes in behavior during the mandatory participation period. They find that the voluntary regime generated inefficient transfers to hospitals and reduced social welfare compared to the status quo, but alternative designs could make transfers more efficient. We complement these results by evaluating outcomes for a chronic condition that extends beyond the first year of bundled payments, exploring heterogeneity across types of patients and providers (e.g., chain vs. independent facilities), assessing several relevant clinical measures (e.g., hemoglobin levels and transfusion rates), and considering the effects on total Medicare spending among all patients and providers due to the narrow composition of the bundle (e.g., spillovers between dialysis facilities and hospitals for transfusions).

On this last point, that the bundled payment in dialysis only partially covers essential treatments, our setting provides a unique opportunity to assess how providers respond to an abrupt move away from fee-for-service reimbursements when the bundle does not include some aspects of care directly influenced by their treatment choices. Compared to the completeness of ACOs and the bundled payment models studied by Einav et al. (2020b), the prospective payment system in dialysis covers some, but not all, of the treatments typically needed by patients with ESRD. Most notably, the dialysis bundle excludes transfusions and hospitalizations, two costly parts of treatment affected by EPO. Our results therefore provide guidance to Medicare on the consequences of not making a bundle truly comprehensive, as providers may respond to their financial incentives in ways that create spillovers for others.

Our paper also relates to past work studying the effects of Medicare's switch from cost-based reimbursements to the diagnoses related group (DRG) system 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 but find that all-cause mortality, cardiovascular mortality, and myocardial infarction did not change

significantly, while Hirth et al. (2014) report an uptick in blood transfusions following the start of the bundle. Our quasi-experimental research design allows us to add to this literature by identifying the causal effect of changes in EPO doses on several health outcomes as well as spillovers to other settings not covered by the bundle.

We also bridge the literature on bundled payments with a large body of work seeking to understand the inefficiencies within the U.S. health care system. These papers have quantified and characterized various sources, including overuse (e.g., testing or treating too much) and misallocation (e.g., testing or treating the wrong patients), often highlighting the financial incentives that influence health care choices more generally, as well as excessive drug doses in particular (Abaluck et al., 2016; Chandra and Staiger, 2017; Currie and MacLeod, 2013; Chan et al., 2019; Clemens and Gottlieb, 2014; Bekelman et al., 2020; Frank and Zeckhauser, 2007). Although prior work has advocated for policies that directly target the underlying inefficiencies (e.g., Garber and Skinner, 2008; Baicker et al., 2012; Glied and Sacarny, 2018), comparatively few studies have examined how bundled payments, one of the most common types of payment reform, affect allocative efficiency. We contribute to this literature by presenting evidence of a costly misallocation, the overuse of injectable drugs for anemia management, and by showing how a bundled payment system improved the allocation of resources for Medicare Part B, which paid $26 billion for injectable drugs on a fee-for-service basis in 2015 (MEDPAC, 2017) and has been a target of policy reforms for several decades (Bach, 2009).

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, 2021; Wilson, 2016a,b). Of particular relevance, Gaynor et al. (2020) study how dialysis providers balance patient health and financial incentives for EPO with a structural model of dosing decisions. Using data from before the bundle, they find that fee-for-service payments resulted in an excessive use of EPO, with doses falling by a third under an optimal linear contract. We complement their work by examining how the change in drug reimbursements affected providers' treatment decisions in practice, as well as the resulting impact on patient outcomes and spillovers.

Our paper proceeds with Section 2, which discusses the details of the U.S. dialysis industry. Section 3 describes our data and presents a preliminary time-series analysis of the payment reform. Section 4 lays out our instrumental variable research design to estimate the causal effects of bundled payments. Section 5 shows how the bundle affected allocative efficiency. Section 6 concludes.

2. Institutional Details of Dialysis

2.1. Medical Background on Kidney Failure

Kidneys filter wastes and toxins out of blood and produce erythropoietin, a hormone that stimulates red blood cell production. For patients with chronic kidney failure, 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. The most common form of dialysis, hemodialysis, uses a machine to artificially clean blood outside the body, either at the patient's home or at a dialysis facility, whereas peritoneal dialysis uses the lining of the patient's abdomen to filter blood inside the body.[1] Because over 90% of dialysis patients in the U.S. use in-center hemodialysis, we focus on that modality for our analysis.[2]

2.2. Medical Background on Anemia

Anemia results from deficient or dysfunctional red blood cells, which leads to reduced oxygen flow to the body's organs. To diagnose anemia and assess its severity, clinicians use either hematocrit concentration, which measures the volume of red blood cells as a percent of total blood volume, or hemoglobin concentration, which measures the amount of hemoglobin, a protein contained in red blood cells, in terms of grams per deciliter of blood (g/dL)[3]. We focus on hemoglobin levels in this paper, with accepted guidelines defining anemia as hemoglobin below 14 g/dL for men and 12 g/dL for women. Common symptoms relate mostly to a patient's quality of life, including fatigue, weakness, headaches, difficulty concentrating, a rapid heart beat, and insomnia, but 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 above, healthy kidneys produce erythropoietin, which stimulates the production of red blood cells in 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.

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

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

[3] Hematocrit is approximately equal to three times the measured hemoglobin level (Bain et al., 2017).

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

By the mid-2000s, randomized controlled trials determined 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 patients treated with EPO to normal or high hematocrit levels who were diagnosed with chronic kidney disease but not on dialysis. Although these randomized controlled trials focused on specific patient populations, they raised concerns about the use of EPO more broadly, 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 period, observational studies suggested similar adverse effects (Zhang et al., 2004; Bradbury et al., 2009; Brookhart et al., 2010), although providers did not change doses much in response (Thamer et al., 2013). In 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.

In addition to EPO, dialysis patients commonly receive a host of other drugs to combat the effects of ESRD, including intravenous iron for anemia management and vitamin D supplements and their analogues to treat hyperparathyroidism and bone mineral disease (Bhan and Thadhani, 2009).

2.3. Medical Background on 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 an increase in both naturally occurring erythropoietin and the amount of iron in the blood

stream. For those with healthy kidneys, erythropoietin stimulates bone marrow to use the available iron to produce red blood cells. In ESRD patients, however, higher elevation is associated with increased iron availability but little increase in erythropoietin, because their kidneys do not properly perform this function. Still, iron makes erythropoietin more productive, so patients at higher elevations tend to have higher baseline levels of hemoglobin and consequently receive less EPO.[4]

Several observational studies in the medical literature have documented this phenomenon. Brookhart et al. (2008), for instance, show that patients living more than 6000 ft. above sea level 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 comparison group, with related results in Sibbel et al. (2017).

2.4. The Dialysis Industry

Dialysis patients choose their provider much like they do in other parts 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). Independent facilities comprise most of the remainder.

Dialysis chains potentially have a number of competitive advantages over independent facilities. Large chains may have lower average costs due to volume discounts for injectable drugs like EPO, for example, as well as centralized clinical laboratories; they may have a stronger bargaining position with commercial insurance companies (Pozniak et al., 2010; League et al., 2021); 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. These uniform 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).

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

2.5. Medicare Payment Reform

Since 1972, Medicare has extended full benefits to all patients with ESRD, regardless of age, paying for both dialysis and anemia treatment under Part B. Those 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 (Lin, 2021).

From the early 1980s to 2011, Medicare paid providers a composite rate of approximately $128 per dialysis session, which was intended to cover the labor, capital, supplies, and routine lab tests associated with each treatment. In addition, Medicare reimbursed providers for EPO and other injectable drugs on a fee-for-service basis. Prior to 2005, the reimbursement rate was statutorily set to $10 per 1000 IUs. In 2005, Medicare updated the rate based on the average sales price plus a 6% markup, resulting in slight decline in reimbursements to about $9.50 per 1000 IUs.[5]. EPO doses and expenditures increased consistently during the fee-for-service era, with spending on erythropoietin stimulating agents (ESAs), such as EPO, approaching $2.7 billion in 2007 (Whoriskey, 2012). Concerns that the distortionary incentives from fee-for-service reimbursements resulted in excessive costs for Medicare and harm to patients motivated policy makers to include ESRD payment reform as a part of the Medicare Improvements for Patients and Providers Act (MIPPA) in 2008.

MIPPA mandated the bundling of dialysis services and all injectable drugs and biologics used in the treatment of ESRD into a single prospective payment, starting in 2011, which was initially set at about $230, a level picked to reduce expected total federal payments to dialysis providers by 2%.[6,7] Although EPO had an outsize effect on patient outcomes, Medicare spending, and provider revenues, the original PPS bundled together 21 other drugs, spanning anemia treatment, access management, and anti-infectives.[8] In addition, the reform explicitly precluded the use of drugs outside the bundle "as substitutes for any of these drugs" included in the bundle, stating that such practices would be "ineligible for separate payment".[9] Despite this clear directive, in practice the reform did not lead to a comprehensive bundle because it only covered reimbursements for one provider, the dialysis facility,

[5]For more details, please see `https://www.gao.gov/assets/260/253347.pdf`.

[6]Federal Register, Volume 74, Issue 187, (September 29, 2009).

[7]Providers had the option to transition into the PPS either immediately in 2011 or gradually over four years starting in 2011. Over 90% opted for the immediate transition. In Appendix I, we demonstrate that our results are robust to using only the set of providers who opted in immediately.

[8]Since then, this list has been expanded to include over 50 products.

[9]Federal Register, Volume 75, Number 155, (August 12, 2010).

leaving open the possibility for facilities to game the reimbursement scheme by pushing patients into treatments delivered elsewhere, like managing anemia with blood transfusions in another setting rather than administering injectable drugs during dialysis. Similarly, facilities could switch their patients to Cinacalcet, a drug used to reduce calcium that was only available in oral form at the time and therefore covered under Part D rather than Part B (Lin and Watnick, 2019). This distinction allowed providers to substitute away from bundled injectables to an unbundled Part D drug.

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, which reduces payments to providers that fail to meet certain clinical standards, such as hemoglobin levels and hospitalization rates. Although the specific criteria assessed in the QIP change from year to year, in its inaugural year, 2012, the QIP standards targeted patient's urea reduction ratio, a measure of the adequacy of dialysis filtration, and hemoglobin levels. Under the QIP, Medicare reduces the annual payments to a facility by 0.5 and 2.0% 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. We discuss the QIP further in Appendix A, where we provide evidence that the QIP did not meaningfully contribute to the reduction in EPO during our sample period.

3. Data, Descriptive Statistics, and Time Trends

The main dataset for our analysis comes from the U.S. Renal Data System (United States Renal Data System, 2019), a clearinghouse 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 data on the health and clinical attributes of patients when they begin dialysis. We also geocode facilities' addresses and extract their elevations using data from the U.S. Geological Survey (U.S. Geological Survey Center for Earth Resources Observation and Science, 2014).

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 instrumental variable analysis in Section 4, the elevation of facilities varies substantially, with a standard deviation of 924 ft. We present summary statistics by elevation in Appendix B.

3.1. Time Trends

The payment reform we study bundled together two types of services that used to be reimbursed separately: dialysis sessions and injectable drugs. Figure 1 shows the evolution of several of these treatments, including anemia management, the quantity and quality of dialysis care, and vitamin D administration. The primary measures of anemia management, EPO doses and transfusion rates, responded immediately to the bundle. For EPO, doses were level going into 2010 but decreased starting midway through 2010 before leveling off again around 2013. The drop in EPO moves in concert with the increase in transfusions shown in panel (b), which is consistent with EPO being used to increase patients' hemoglobin levels and reduce their need for transfusions. The sharp decline in EPO predates the payment reform in 2011 by a few months and matches Medicare's announcement of the final PPS rule.[10] For that reason, we use January 2011 as the beginning of the bundle in our main analysis but show in Appendix C that our results are robust to changing the treatment period to also include the anticipatory period between the announcement and the implementation of the bundle.[11] Likewise, panels (c) and (d) show the trends for vitamin D supplements and their substitute, Cinacalcet, with a drop in the use of vitamin D corresponding with the payment reform coupled with an increase in the use of Cinacalcet. As discussed above, these patterns reflect a spillover to Part D drugs due to Medicare's decision not to make the dialysis bundle comprehensive.

In contrast to the changes in anemia treatment, we find little evidence that dialysis care itself changed

[10] For more details, please see `https://www.gao.gov/assets/gao-13-190r.pdf`.

[11] Also, as discussed in Section 2.2, during this period there were two other policy changes of note, a black box warning and the QIP. In Appendix A, we present evidence that these changes do not explain the decline in EPO doses in Figure 1 — if anything, they would make our estimate of the bundle's effect on EPO doses conservative.

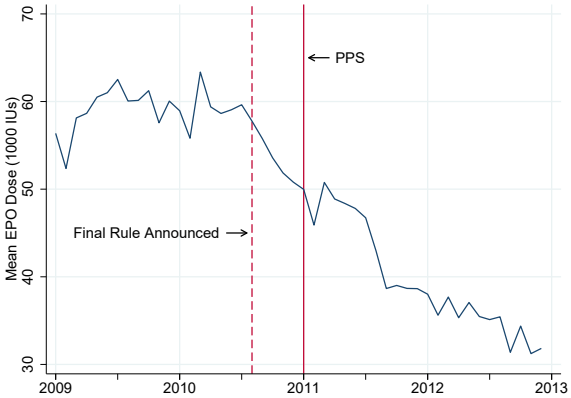
Table 1
Patient Descriptive Statistics

	Mean	Std. Dev.
Patient Characteristics		
Predicted Mortality	0.016	0.011
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)	48.50	64.11
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	461,477	
Patient-Months	10,077,289	

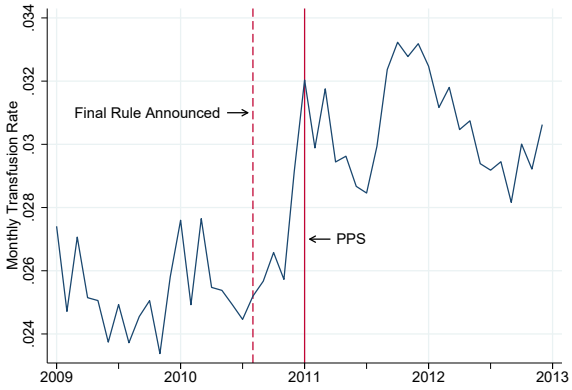
Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the analyses in Section 3.1 and later. Predicted mortality is the predicted value for each observation using coefficents from a regression of mortality on patient controls and time fixed effects on observations from 2009 and 2010. 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 censored at the 99th percentile and measured in 1000 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.

Figure 1
Time Trends in Treatments and Outcomes

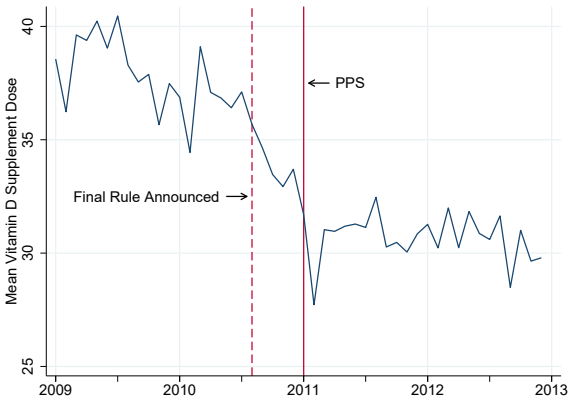
(a) Monthly EPO Dose



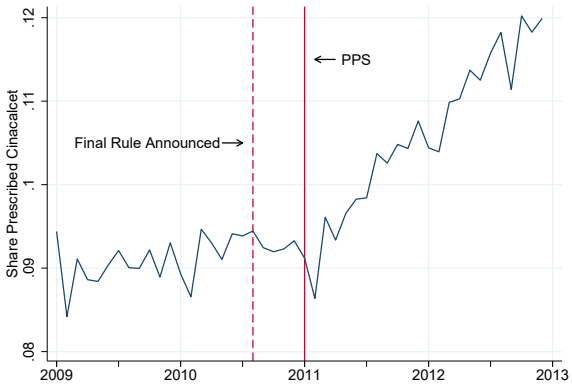
(b) Transfusion Rate



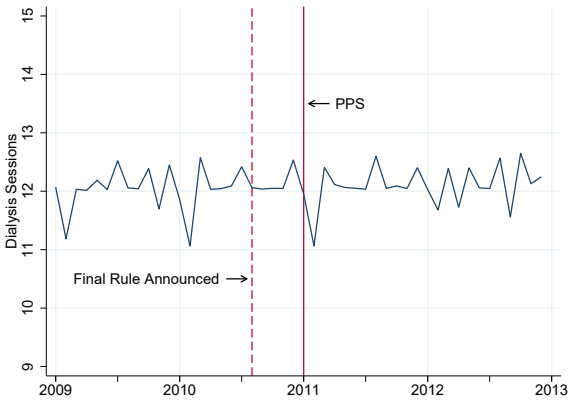
(c) Monthly Vitamin D Dose



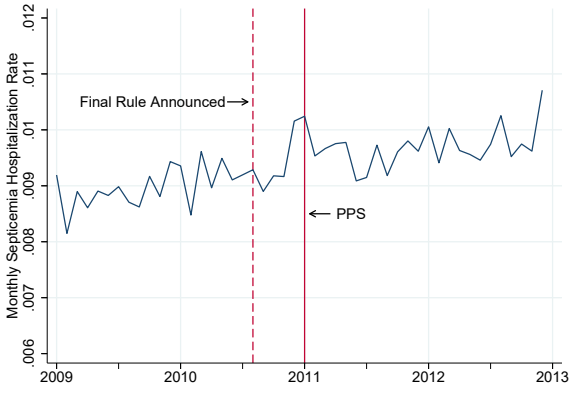
(d) Share Prescribed Cinacalcet



(e) Monthly Dialysis Sessions



(f) Hospitalizations for Septicemia



Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 censored at the 99th percentile and measured in 1000 IUs. Injectible vitamin D drugs include Calcitriol, Doxercalciferol, and Paricalcitol. The solid vertical line indicates the start of PPS in January 2011, while the dashed vertical line indicates the announcement of the final rule for PPS.

in response to the payment reform. For instance, the average number of dialysis sessions per patient remains steady each month throughout the payment reform, and hospitalizations for septicemia, a class of infections that can arise from improper cleaning of dialysis facilities, thereby reflecting low-quality care, did not increase.

The trends in EPO doses and transfusions indicate that providers responded to the bundle by cutting EPO doses, leading to an increase in transfusions. Although this suggests that outcomes deteriorated for at least some patients, to understand the full implications of using fewer resources in anemia management, we must first disentangle how the change in EPO was distributed across patients. To this point, Figure 2 shows the amount of EPO given to patients with various HGB levels over time, with the largest decrease coming from the least anemic patients — those with HGB levels above 12g/dL — while patients with lower HGB levels, who are in greater need of EPO, experienced relatively smaller decreases. For women with HGB levels above 10 g/dL and men above 12 g/dL, the potentially harmful side effects of EPO likely outweigh the drug's benefits.

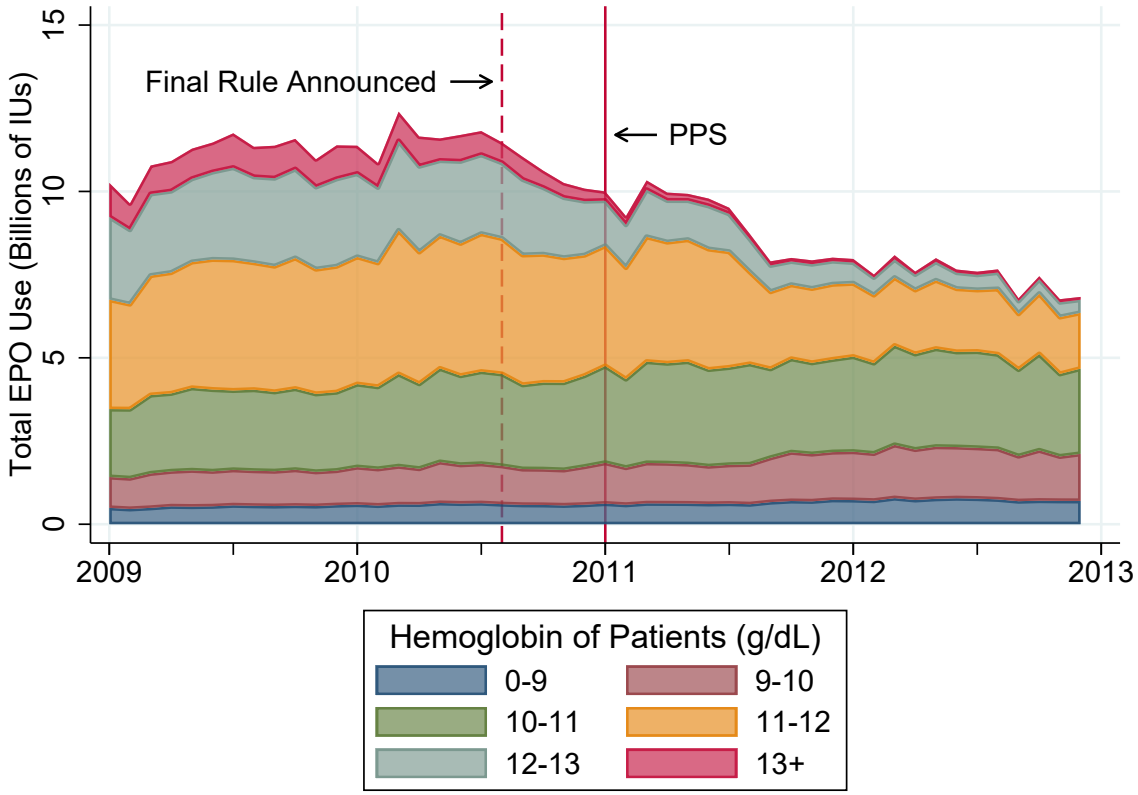
In this way, allocative efficiency may have improved following the bundle as providers concentrated the decrease in EPO among patients who were previously receiving doses that put their HGB levels above the recommended range. A purely descriptive approach such as this may obscure important mechanisms, however, as a patient's EPO dose is not exogenous — it depends on the patient's underlying health. For that reason, we use an instrumental variables approach to better identify the marginal effect of EPO and conduct a more thorough analysis of the allocation of EPO in Sections 4 and 5.

Although the measures above comprise the primary channels through which the payment reform may have affected patient care, we explore others in Appendix H. We document a small shift from hemodialysis toward peritoneal dialysis, a change that may have resulted from a relative increase in its profitability after the bundle (Zhang et al., 2017). In addition, the incentives governing other drugs may have changed depending on whether they were included in the bundle, like we showed for vitamin D and Cinacalcet above, as well as other injectable drugs like intravenous iron in Figure A11.

3.2. Preliminary Analysis of the Bundle

For a preliminary analysis of how the payment reform influenced provider behavior and patient outcomes, we consider the following regression that includes an indicator variable for the post-PPS

Figure 2
EPO Use by HGB Level



Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 censored 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 start of PPS in January 2011, while the dashed vertical line indicates the announcement of the final rule for PPS.

period as well as 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 calendar month, patient, and facility fixed effects. This specification suggests a within-patient decrease in EPO doses of over 9% from the pre-bundle mean.[12] In Table 3,

[12]The smaller magnitude of the PPS coefficient in specification (4) that includes patient fixed effects is not driven by new patients, as the decrease in EPO was similar for both new and continuing patients. Furthermore, the reduction in EPO occurred for those who began dialysis before the final rule was announced just as much as for those beginning dialysis later.

Table 2
Effect of Bundle on EPO Dose

	(1) EPO	(2) EPO	(3) EPO	(4) EPO
PPS	-18.31***	-19.92***	-16.99***	-5.679***
	(0.245)	(0.238)	(0.417)	(0.266)
Pat/Fac Controls	0	1	1	1
Facility FE	0	0	1	1
Patient FE	0	0	0	1
Dep. Var. Mean	48.50	48.50	48.50	48.54
R-squared	0.0203	0.0777	0.134	0.531
Observations	10077289	10077289	10077264	10059269

Notes: OLS estimates from equation (1). Dependent variable is monthly EPO dose. EPO doses are censored at the 99th percentile and measured in 1000 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 in-center 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 calendar 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.

we present results from estimating the same specification for other dependent variables, finding large changes after the bundle: HGB levels decline 3.9%, transfusions increase 21.5%, overall hospitalizations drop 3.4%, hospitalizations for cardiac events decrease 6.9%, and the monthly mortality rate falls 4.8%.[13]

Although easy to interpret, these initial time-series regressions may be biased by confounding time trends. Figure 1, for instance, 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 the PPS indicator variable:

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

Equation (2) differs from (1) with the inclusion of two time trend terms, t and $t_{Post\text{-}PPS}$. Here, t

[13]Table in Appendix B gives the pre-bundle means for these variables, which are used as the denominators for these percentage change calculations.

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***	-0.00490***	-0.00202***	-0.000815***
	(0.00888)	(0.000201)	(0.000460)	(0.000195)	(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	0.0271	0.0157
R-squared	0.0749	0.0118	0.0215	0.00790	0.00850
Observations	8181736	10077264	10077264	10077264	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 in-center 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 is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% level, respectively.

and $t_{Post\text{-}PPS}$ measure the number of months since the the start of the bundle in January 2011.[14] We therefore interpret β_1 as the average monthly change in EPO before the start of the bundle, while β_3 is the change in this trend after the bundle. Complete estimates of equation (2) appear in Appendix E.

Column (1) of Table A12 presents results from estimating equation (2) with EPO as the dependent variable. We find that EPO doses were declining by approximately 0.4% each month prior to the bundle, which increases in magnitude to 1.8% after the bundle, in addition to the immediate decrease of approximately 14.1%. Compared to our results from equation (1), this suggests the effects of the bundle did not become fully realized in January 2011, but instead evolved more gradually over time.

For other outcomes in Table A12, we find that, consistent with the contemporaneous reduction in EPO, transfusions increased after the bundle, although with a moderated upward trend. For any-cause hospitalizations, we estimate a pre-existing downward trend that roughly doubles in magnitude after the bundle, in line with the drop in EPO and the risks associated with the drug. By December of 2012, we find a 6.3% decrease in hospitalizations relative to December 2010. Rates of both hospitalization for cardiac events and mortality were decreasing in the pre-period and declined further following the start

[14]The variable t takes on negative values prior to the start of the bundle in January 2011 such that in December 2010 $t = -1$, in November 2010 $t = -2$, and so on; $t_{Post\text{-}PPS}$ is set to 0 for all months prior to the start of the bundle. Please see Baicker and Svoronos (2019) for a discussion of the benefits of this definition of time trends.

of the bundle, although the changes are not statistically significant.[15]

4. Instrumental Variables Analysis

Our descriptive results from Section 3 suggest the payment reform had a large impact on anemia treatments, with EPO doses falling sharply and other injectable drugs included in the bundle showing similar declines. Properly evaluating how these changes were distributed across patients and how they ultimately affected health outcomes requires us to first estimate the marginal harm or benefit of EPO. In this section, we present our approach for identifying this effect.

4.1. Identification Strategy

Consider the average 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 a patient's declining health.

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 bundled payment policies. As Medicare imposed the change uniformly on all providers, rather than targeting specific payment changes to specific facilities, this policy introduced a plausibly exogenous shock to EPO doses due to the change in financial incentives. Second, we use a novel source of variation based on a 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. With facilities considering both their own profits and a patient's well-being when

[15] We similarly find that trends in Medicare spending changed following the bundle, as shown in Table A26.

prescribing EPO, those at lower elevations should reduce their doses comparatively more after the bundle eliminated fee-for-service reimbursements. In other words, 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 identify the causal effect of EPO on health outcomes.

We cannot simply use the payment reform and elevation as instruments directly in equation (3), however, as doing may violate the exclusion restriction. Causal inference using changes before and after Medicare introduced bundled payments would require us to assume that the change in EPO was the only change that could have affected patient health, but other trends, such as updated dialysis standards and related medical advances, may be conflated 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' hemoglobin levels, it may also directly affect other health outcomes.

Rather than use either variable as an instrument on its own, we instead 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 fixed effects 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 first stage resembles a difference-in-differences estimation, 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 period when the financial incentives flipped. As outlined in Nunn and Qian (2014), the main distinction between this strategy and a typical

difference-in-differences estimation is the continuous treatment variable.

For our second stage 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 the payment reform 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 deliberately choose their location based on patients' potential outcomes. By interacting the two variables, however, the reduced-form coefficient only measures how the slope between elevation and outcomes changes when facilities start receiving 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 difference-in-differences estimation, a plot of EPO doses over time for the first and fifth elevation quintiles in the left panel of Figure 3 shows parallel trends in EPO doses prior to the bundle.[16] On average, low-elevation patients received higher doses of EPO before the bundle, with the difference between the two groups remaining constant during this period.[17] 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.[18] The second stage links the change in EPO to related health outcomes like transfusions, with the right panel showing a larger increase for patients at lower elevations commensurate with their larger reduction in drug doses.

A related threat to identification would be omitted variables that change disproportionately across elevations over time. From balance tables for observable patient characteristics at each elevation quintile

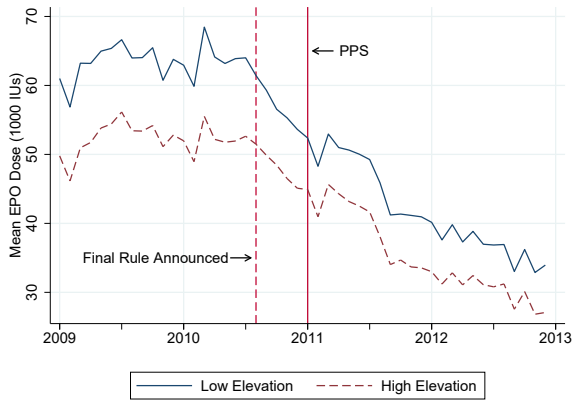
[16] As discussed in Christian and Barrett (2017), non-parallel pre-trends would have suggested our difference-in-differences analog violated the exclusion restriction.

[17] A regression of EPO on facility elevation, a time trend, and the interaction of the two along with patient and facility controls using data prior to the bundle indicates that the difference in time trends is small and not statistically significant (p=0.5777).

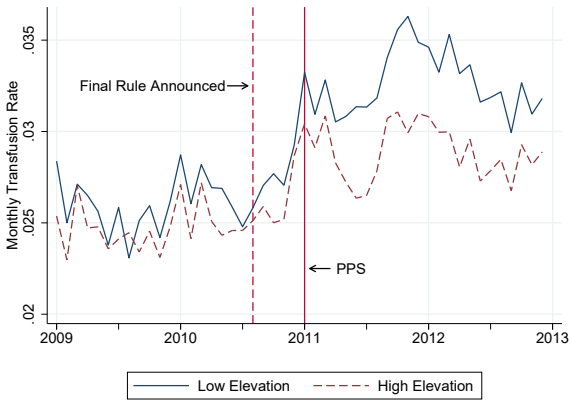
[18] This differential response to a uniform change in financial incentives suggests nonlinearities in the marginal effects of EPO across elevations and highlights the importance of interpreting our second-stage estimates as average causal effects from a heterogeneous effects model.

Figure 3
Mean EPO Dose and Transfusion Rate Over Time, by Elevation

(a) First Stage: EPO



(b) Second Stage: Transfusions



Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 censored at the 99th percentile and measured in 1000 IUs. High (low) elevation denotes facility elevation in the fifth (first) quintile. This corresponds to being above 870 (below 73) feet above sea level. The solid vertical line indicates the start of PPS in January 2011, while the dashed vertical line indicates the announcement of the final rule for PPS.

in Appendix B, we find that, although some differences across elevations exist and change over time, the changes are not systematically moving towards better or worse outcomes across elevations. To assess more formally whether changes in unobserved patient characteristics 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. This predicted mortality variable is likely correlated with unobserved characteristics that affect their health, and we can detect changes in the composition of the patient population by testing if predicted mortality changed differentially by elevation after the bundle. Estimating equation (4) with predicted mortality as the dependent variable, we show in Table 4 that the differential change by elevation is a precisely estimated zero, which suggests that a changing mix of patients across elevations is unlikely to confound our analysis.

Another violation of the exclusion restriction could come from facilities reinvesting the additional profits they earn from administering less EPO after the bundle goes into effect. For instance, facilities at higher elevations use less EPO and therefore received disproportionately larger financial benefits from

Table 4
Predicted Mortality by Elevation

	(1) Predicted Mortality	(2) Predicted Mortality	(3) Predicted Mortality
Facility Elevation	0.000000182**	0.000000165**	0.000000100
	(5.95e-08)	(6.05e-08)	(0.000000175)
Elevation × PPS	-7.62e-08***	-4.43e-08^{+}	-3.20e-08
	(2.03e-08)	(2.37e-08)	(1.98e-08)
Year-Month FE	0	1	1
Pat/Fac Controls	0	0	0
Facility FE	0	0	1
R-squared	0.000167	0.000431	0.134
Dep. Var. Mean	0.0164	0.0164	0.0164
Observations	10077289	10077289	10077264

Notes: OLS estimates from equation (4). Dependent variable is predicted mortality. Predicted mortality is the predicted value for each observation using coefficents from a regression of mortality on patient controls and time fixed effects on observations from 2009 and 2010. 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 in-center 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 5
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	0.0000230^{+}	-0.000175***	-0.000182***	-0.0000158**	-0.000000699***
	(0.0000128)	(0.0000196)	(0.0000260)	(0.00000598)	(0.000000129)
Elevation × PPS	0.00000839	0.0000345	0.00000562	-0.00000590^{+}	0.0000000336
	(0.00000858)	(0.0000232)	(0.0000167)	(0.00000357)	(0.0000000786)
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	0.00103	0.00628	0.00339	0.000968	0.00283
Dep. Var. Mean	0.910	5.402	3.988	0.766	0.00939
Observations	242917	254307	256712	256173	10077289

Notes: OLS estimates from equation (4). Dependent variables in columns (1)–(4) are facility-level ratios. Dependent variable in column (5) is an indicator for hospitalization with a primary diagnosis of septicemia. PPS is an indicator variable for January 2011 or later. Facility elevation is measured in feet above sea level. For columns (1)–(4) an observation is a facility-month. For column (5) an observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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. For columns (1)–(4) controls are facility-month-level means of the patient-level controls. Standard errors clustered by facility are in parentheses. $^{+}$, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% level, respectively.

Medicare's switch to a prospective payment system; these facilities may have reinvested their financial windfall in ways that improved patient care. As shown in Table 5, however, we find no evidence of such behavior, as conventional measures of a facility's investment in providing high-quality care, such as the number of patients per staff, the number of patients per station, and patient infection rates, do not differentially change by elevation after the payment reform.

4.2. Instrumental Variables Results

We present results from our first-stage estimates in Table 6, with an F-statistic of 49.1 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 over a quarter after the bundle. Specifically, estimates from our preferred specification presented in column (3) indicate that patients at sea level saw their average monthly EPO dose reduced by 1,400 IUs more than those living at an elevation of 1,000 ft. 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 levels, blood transfusions, hospitalizations, and mortality.

Table 6
First Stage Regression

	(1) EPO	(2) EPO	(3) EPO
Facility Elevation	-0.00477***	-0.00353***	-0.00542***
	(0.000341)	(0.000401)	(0.00157)
Elevation × PPS	0.00144***	0.00133***	0.00140***
	(0.000214)	(0.000203)	(0.000200)
Year-Month FE	1	1	1
Pat/Fac Controls	0	1	1
Facility FE	0	0	1
R-squared	0.0297	0.0835	0.139
Dep. Var. Mean	48.50	48.50	48.50
Observations	10077289	10077289	10077264

Notes: OLS estimates from equation (4). Dependent variable is monthly EPO dose. EPO doses are censored at the 99th percentile and measured in 1000 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 in-center 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 is freestanding or hospital-based, and chain ownership, 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.

The results for HGB levels 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 7 shows the opposite effect, however, 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), where increasing EPO doses by 1000 IUs per month increases a patient's HGB by 0.0208 g/dL, on average, confirming the established medical fact that EPO effectively treats anemia. Table 7 also shows results with transfusions as the

Table 7
The Effect of EPO on Hemoglobin Levels and Transfusions

	HGB		Transfusion	
	(1) OLS	(2) IV	(3) OLS	(4) IV
EPO	-0.00303***	0.0208***	0.000132***	-0.000574***
	(0.0000254)	(0.00542)	(0.00000256)	(0.000153)
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		33.41		49.11

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 variable in columns (3)–(4) is a binary variable for receiving a blood transfusion. EPO doses are censored at the 99th percentile and measured in 1000 IUs. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 is freestanding or hospital-based, and chain ownership, 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.

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 8 that larger EPO doses lead to more hospitalizations for cardiac events and higher mortality rates. For both all-cause and cardiac hospitalizations, the OLS and IV results suggest a positive correlation with EPO doses, although this effect does not remain statistically significant for all-cause hospitalizations in the IV specification. 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 4.8% 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

Table 8
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	0.000154***	0.000201	0.0000153***	0.000181+	-0.000000269	0.0000351	-0.000112***	0.000126*
	(0.00000348)	(0.000249)	(0.00000121)	(0.0000942)	(0.000000602)	(0.0000538)	(0.000000893)	(0.0000631)
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		49.11		49.11		49.11		49.11

Notes: OLS and IV estimates from equation (3). Dependent variables are binary outcomes. EPO doses are censored at the 99th percentile and measured in 1000 IUs. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 is freestanding or hospital-based, and chain ownership, 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.

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 that an omitted variable confounds our analysis. As shown in Table 8, we do not find a causal effect of EPO on septicemia in our IV specification, providing some reassurance that our approach is valid.

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 death.

5. Changes in the Allocation of EPO

A primary reason policy makers adopt bundled payment systems is to curtail providers' inefficient use of resources. The sharp drop in EPO and other injectable drugs following the payment reform ostensibly achieved this aim. If facilities reduced doses indiscriminately across all patients, however, then the move to bundled payments may have been less effective than if they had instead focused their cuts on those patients who receive little benefit from the drugs. To describe how allocative efficiency changed following the bundle, we extend our instrumental variables 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 benefit for some patients while others may see no benefit at all. If providers concentrated their cuts on the latter

group, then this suggests that the bundle increased allocative efficiency.[19]

5.1. Predicting Patients' Response to EPO

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

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

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

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

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

$$\frac{\partial T_{ijt}}{\partial E_{ijt}} = \beta_1 + \beta_3 X_{it}.^{20} \tag{7}$$

We consider two dependent variables associated with anemia, HGB levels and 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 transfusions but provide a similar analysis for HGB levels in Appendix F.

To estimate equation (6), we extend our instrumental variables strategy from Section 4. As before,

[19] 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 transfusions and hemoglobin.

[20] This specification only allows the returns from EPO to vary by patient attributes, not by facility characteristics. Different facilities may 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 T_{ijt} could change, but the marginal effect of EPO, $\partial T_{ijt}/\partial E_{ijt}$, 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. Nonetheless, our results are robust to allowing the marginal effect of EPO to vary by facility characteristics as well.

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, by interacting it with each patient attribute and use these as a new set of instruments. For example, we instrument for the difference in the marginal effect of EPO for men and women using 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, with coefficient estimates provided in Appendix G.

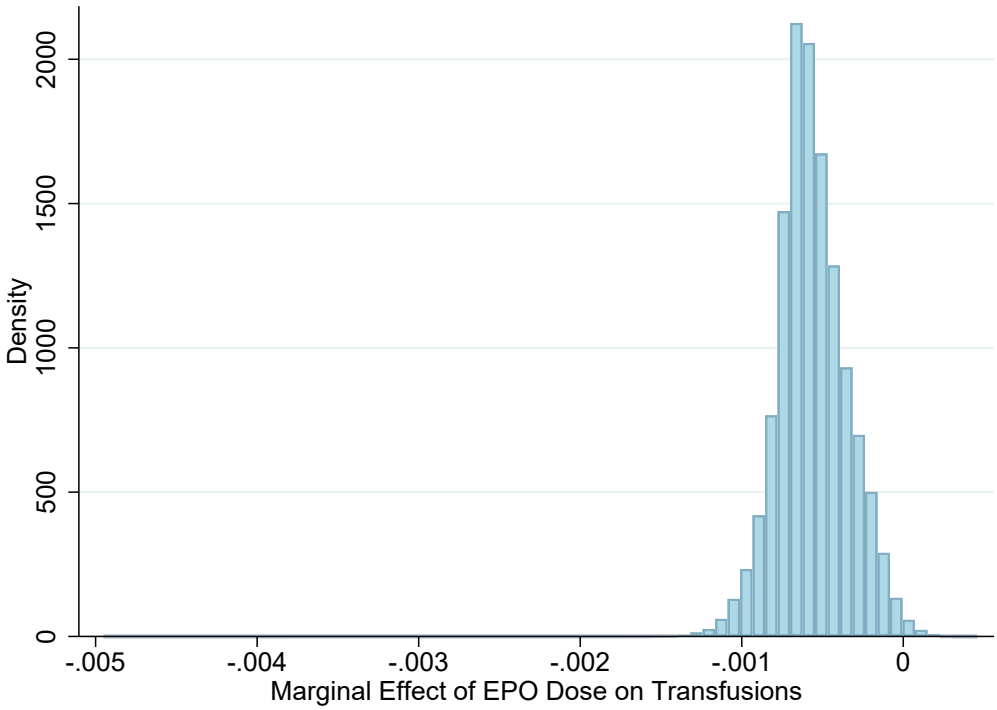
5.2. The Allocation of EPO and Its Effect on Blood Transfusions

Figure 4 shows the distribution of the predicted marginal effect of EPO on blood transfusion rates for all patient-month observations. Here, the average marginal effect is -0.0006, which is nearly identical to the local average treatment effect estimated in Section 4, with the distribution mostly falling between -0.001 and 0. The wide variation in patients' responsiveness to EPO has important practical implications: the marginal effect of EPO is twice as large for a patient one standard deviation more responsive than the mean compared to a patient one standard deviation less responsive.

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), $\overline{\frac{\partial T_i}{\partial E_i}}$. To make it easier to interpret our results, we multiply the average marginal effect by -1 and then normalize it by converting it to a Z-score, which we map to a patient's EPO-responsiveness type.[21] Patients who are very responsive to EPO are those whose average marginal effects are larger in absolute value, whereas patients who are relatively unresponsive to EPO are those whose average marginal effects are close to zero. Put differently, EPO is more effective at reducing transfusion rates for patients who are highly responsive to the drug. We call a patient's Z-score for transfusions Z_{T_i}.

[21] Since the benefit from EPO is a negative marginal effect on transfusions, we multiply it by -1 to facilitate the interpretation of the Z-score as the degree to which the patient responds to EPO. The result is that patients for whom EPO did the most to decrease transfusions (i.e., large negative marginal effects) will have the highest (i.e., most positive) Z-score. When we look at responsiveness in terms of HGB, we call it Z_{HGB_i} and do not multiply the marginal effects by -1, because the benefit of EPO in terms of this variable is its ability to raise a patient's HGB.

Figure 4
Histogram of Predicted Marginal Effects ($\widehat{\frac{\partial T_{ijt}}{\partial E_{ijt}}}$) of EPO on Transfusions



Notes: Predicted marginal effects 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 in-center 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 censored at the 99th percentile and measured in 1000 IUs.

The patients most responsive to EPO have different observable characteristics than those who are less responsive, as shown in Table 9 that compares the attributes of patients across responsiveness quintiles. Patients in the first quintile are the least responsive to EPO, meaning that EPO has only a small effect on their transfusion rates, and we call this group of patients "unresponsive." Conversely, we call patients from the fifth quintile "responsive." 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. Unresponsive patients have the highest predicted and realized mortality rates, have more hospitalizations, are older, and have more-severe anemia. Before the bundle, these unresponsive patients also received the largest doses of EPO yet still required the most transfusions, which we interpret as wasted resources: facilities responded to the financial incentives of fee-for-service reimbursements by administering as much EPO as possible, subject to keeping a patient's HGB level just under the recom-

mended upper limit. Although theoretically possible that transfusion rates could have been even higher for unresponsive patients had they not received such large doses of EPO, we show in our analysis below that this is not the case.[22]

In Figure 5, we decompose the trends in EPO over time by patient responsiveness. Panel (a) shows that although EPO doses fell for both groups, the drop was greater for unresponsive patients. Prior to the bundle, unresponsive patients actually received more EPO than the responsive patients even though responsive patients receive a larger marginal benefit 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 the doses they receive. As shown in panel (b), however, the drop in EPO only affects the transfusion rates of the responsive group — transfusion rates continued a downward trend for the unresponsive patients even though they had a larger drop in EPO compared to responsive patients, for whom transfusions increased. These results suggest a marginal misallocation of EPO prior to the bundle, as unresponsive patients experienced large decreases in their doses with no corresponding increase in transfusions. By contrast, transfusion rates increased for responsive patients, and these increases likely would have been even larger had they received the same proportional cuts in EPO as the unresponsive patients did.

Building on the results in Figure 5, we consider the differential effects of the bundle for patients of varying degrees of responsiveness by estimating the regression

$$Y_{ijt} = \alpha_0 + \alpha_1 Z_{T_i} + \alpha_2 I[PPS_t = 1] + \alpha_3 Z_{T_i} \times I[PPS_t = 1] + \alpha_4 t + F_{jt}\Gamma + u_{ijt}, \tag{8}$$

for three dependent variables — EPO doses, transfusion rates, and mortality — and include facility-level controls defined in Section 3.1 and facility fixed effects in F_{jt}.[23] In this setup, EPO doses describe the intensity of treatment, while transfusion rates and mortality capture the resulting health outcomes. Finally, we use two different approaches for including our standardized measure of EPO-responsiveness with respect to blood transfusions: (i) we include the measure as a continuous linear variable and (ii)

[22]The results in Table 9 show that patients with larger marginal benefits with respect to transfusions tend to experience fewer hospitalizations and have lower death rates, measured in absolute levels. We have also checked the correlations between the marginal benefits with respect to transfusions and any-cause hospitalizations, cardiac hospitalizations, and death, and find them to all be positively correlated. That is, those patients for whom EPO helps reduce transfusions are the same patients for whom EPO has a comparatively smaller risk of increasing the probability of either type of hospitalization as well as death.

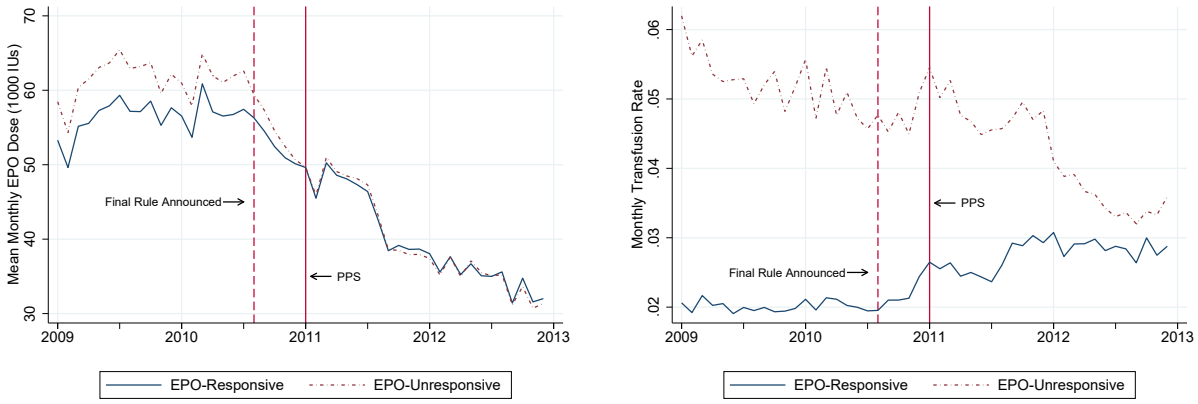
[23]Please see Appendix G for other dependent variables: HGB levels, hospitalizations, and Medicare spending.

Table 9
Descriptive Statistics by Responsiveness of Transfusion Rate to EPO

	EPO-Responsiveness Quintile				
	First	Second	Third	Fourth	Fifth
Patient Characteristics					
Marginal Effect of EPO	-0.0002	-0.0004	-0.0005	-0.0006	-0.0008
Predicted Mortality	0.022	0.017	0.015	0.014	0.017
Age (Years)	67.99	63.27	62.25	62.15	63.86
Months with ESRD	22.94	45.13	45.43	43.69	44.04
Black	0.354	0.464	0.463	0.418	0.225
Male	0.647	0.613	0.579	0.513	0.460
Diabetic	0.519	0.514	0.516	0.523	0.557
Hypertensive	0.965	0.969	0.963	0.939	0.742
Incident Hemoglobin	9.687	9.625	9.772	10.018	10.315
Facility Characteristics					
Facility Elevation (ft)	680.3	638.9	626.5	634.3	630.4
Independent Ownership	0.223	0.210	0.212	0.212	0.234
Resource Use					
EPO Dose (1000 IUs)	61.69	61.08	59.56	58.76	56.13
Receives Any EPO	0.720	0.769	0.781	0.780	0.780
Medicare Spending ($)					
Total	10,114	7,578	7,087	6,977	6,965
Inpatient	4,457	2,634	2,300	2,253	2,259
Dialysis	2,081	2,259	2,279	2,271	2,240
Part D	322	409	429	434	437
Outpatient	454	379	355	336	344
Health Outcomes					
Hemoglobin (g/dL)	11.30	11.46	11.48	11.47	11.47
Mortality	0.042	0.014	0.012	0.013	0.014
Hospitalizations					
Any Cause	0.2242	0.1445	0.1300	0.1286	0.1304
Cardiac Event	0.0446	0.0286	0.0260	0.0265	0.0281
Septicemia	0.0195	0.0085	0.0070	0.0070	0.0073
Transfusions					
Total	0.0534	0.0250	0.0207	0.0198	0.0199
Inpatient	0.0446	0.0207	0.0169	0.0159	0.0160
Outpatient	0.0104	0.0048	0.0043	0.0042	0.0044
Emergency Room	0.0002	0.0001	0.0001	0.0001	0.0001
Unique Patients	44,987	46,786	52,660	55,416	56,655
Patient-Months	285,302	421,733	519,378	555,605	568,424

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 using coefficents from a regression of mortality on patient controls and time fixed effects on observations from 2009 and 2010. Time fixed effects are not included in the prediction. EPO doses are censored at the 99th percentile and measured in 1000 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).

Figure 5
EPO Dosing and Transfusion Rates Over Time by Responsiveness of Transfusion Rates to EPO



(a) Monthly EPO Dose

(b) Transfusion Rate

Notes: "EPO-responsive" ("EPO-unresponsive") refers to patients with average estimated marginal effects of EPO on transfusions in the fifth (first) quintile of absolute value. This corresponds to being at least 0.73 standard deviations above (0.78 standard deviations below) the average estimated marginal effect. Marginal effects are recovered from IV estimates of equation (6). An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 censored at the 99th percentile and measured in 1000 IUs. The solid vertical line indicates the start of PPS in January 2011, while the dashed vertical line indicates the announcement of the final rule for PPS.

we include a series of indicator variables for each individual's EPO-responsiveness quintile. Although we prefer the second specification because it is less parametric, it is also more cumbersome to interpret. As such, we include the linear estimates here in Table 10 and present highlights from the nonlinear estimates in Figure 6, with the complete tables for these estimates appearing in Appendix G.

Columns (1) and (2) in Table 10 suggest a misallocation of EPO prior to the bundle. Under fee-for-service reimbursements, patients with an EPO-responsiveness one standard deviation below the mean received, on average, 2.8% *more* EPO than patients at the mean. This pre-bundle gradient suggests that providers wasted EPO on unresponsive patients, whose transfusion rates do not respond to the marginal EPO dose.[24] Although these patients appear to have received no direct benefit from the large doses

[24]Our interpretation that the EPO given to unresponsive patients was waste relies on the assumption that the benefits of EPO translate into observable health outcomes. We cannot completely rule out the possibility that this EPO had some value to patients, such as improving their quality of life, and that the larger observed doses under fee-for-service were the result of unresponsive patients requiring higher doses to achieve the providers' targeted outcomes. We find this unlikely since it would require the responsiveness of the latent outcome to be inversely correlated with the responsiveness of all the observed outcomes we have explored, as in footnote 22. Even if this were the case, however, the pronounced drop in EPO still highlights the extent to which financial incentives influence treatment decisions.

of EPO, the facilities themselves benefited 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. During the post-bundle period, patients with an EPO-responsiveness one standard deviation below the mean receive, on average, 0.8% less EPO than patients at the mean.

Table 10
Difference in EPO and Health Outcomes by Patient Responsiveness to EPO

	(1) EPO	(2) EPO	(3) Transfusion	(4) Transfusion	(5) Mortality	(6) Mortality
EPO-Responsiveness Z-Score	-1.369***	-1.197***	-0.00988***	-0.00986***	-0.00822***	-0.00823***
	(0.106)	(0.106)	(0.000166)	(0.000165)	(0.000108)	(0.000108)
PPS	-6.343***		0.00484***		0.0000213	
	(0.275)		(0.000292)		(0.000182)	
EPO-Responsiveness Z-Score × PPS	1.778***	1.414***	0.00420***	0.00414***	0.00440***	0.00441***
	(0.107)	(0.107)	(0.000180)	(0.000181)	(0.000110)	(0.000111)
Time Trend	-0.523***		-0.0000787***		-0.000109***	
	(0.0146)		(0.0000123)		(0.00000805)	
Facility Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1
R-squared	0.121	0.123	0.00916	0.00920	0.00483	0.00484
Dep. Var. Mean	48.50	48.50	0.0282	0.0282	0.0157	0.0157
Observations	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 censored at the 99th percentile and measured in 1000 IUs. Dependent variables in columns (3)–(6) 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. EPO-Responsiveness 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 in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 columns (3) and (4), we show that, prior to the bundle, patients who responded more to EPO were less likely to need blood transfusions. After the bundle, the transfusion rate rose overall, but those patients who experienced the largest decrease in EPO actually required fewer transfusions, bolstering our interpretation that EPO was wasted on unresponsive patients. Columns (5) and (6) show similar trends for mortality. Taken together, these results indicate that the decrease in EPO following the payment reform was so large that it caused comparatively more adverse outcomes among the EPO-responsive patients despite the reallocation of EPO towards them from the unresponsive patients.

Figure 6 shows analogous results based on estimates of the nonlinear version of equation (8). In the pre-bundle period, patients in the lowest responsiveness quintile received the most EPO, whereas the most-responsive patients received the least. After the bundle, transfusion rates for the least-responsive patients fell 17.3% despite their comparatively larger drop in EPO doses. Adverse outcomes associated with excessive EPO also subsided for this group, with mortality rates declining 37.9% and hospitalizations for cardiac events declining 21.6%, as shown in Figure A10 in Appendix G.[25] The large improvements in health outcomes for unresponsive patients stand in contrast to the changes for more-responsive patients, who experienced a statistically significant increase in transfusion rates accompanied by a relatively small increase in mortality, while cardiac hospitalizations also increased slightly, as shown in Figure A10.

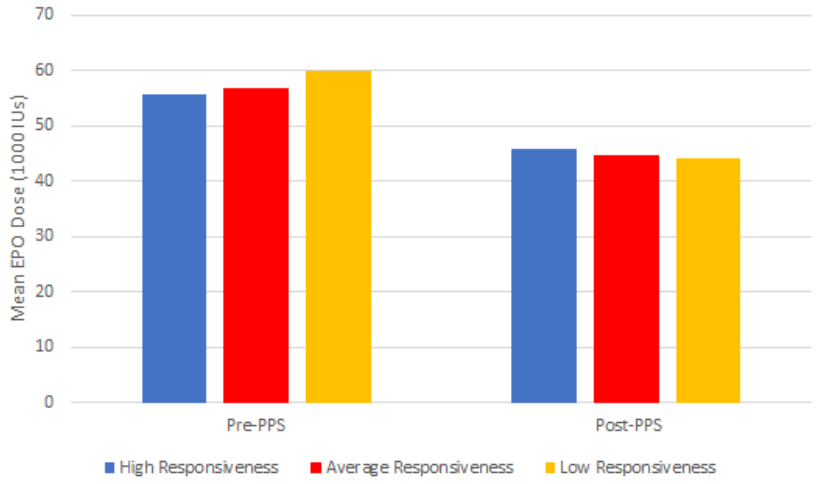
Importantly, our setting also allows us to consider how the bundle creates spillovers for other parts of the health care system not directly targeted by the payment reform. Figure 7 provides evidence of these spillovers, where total spending on EPO-unresponsive patients fell 13.8% after the bundle. The change is primarily driven by the 25.5% decline in inpatient spending, reflecting the significant drop in cardiac hospitalizations stemming from the lower doses of EPO. In addition, the 9.6% decline in the average EPO dose from our most-conservative specification suggests that the bundle caused a 13.0% increase in transfusions, given the average treatment effect of EPO on transfusions. This represents a shift in anemia management from a treatment included in the bundle, EPO, to one excluded from it, transfusions.

5.3. Differences in Allocative Efficiency Across Chains

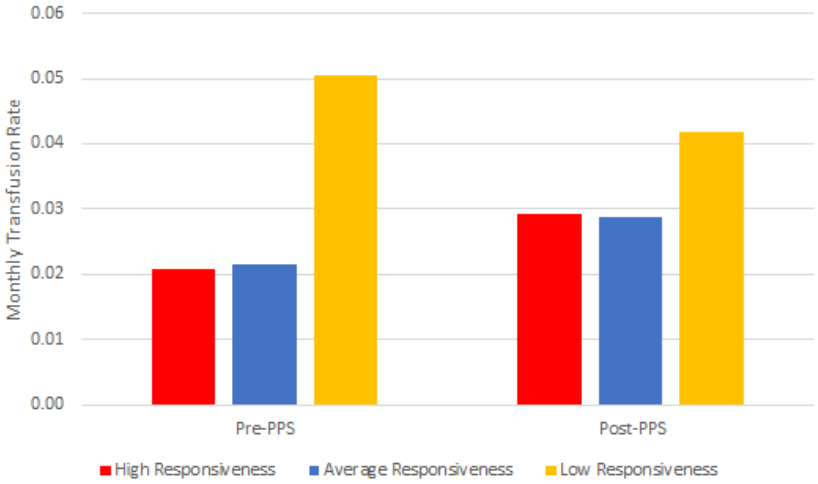
We also find that chain-owned facilities behave differently than independent facilities with respect to EPO, both before and after the bundle. Interacting the chain status of each facility with equation (8), we show in Table 11 that chains used much more EPO in the pre-bundle period and had a larger 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.

[25]Panel (a) of Figure A10 also shows that HGB levels fell more for EPO-responsive patients, consistent with their increase in transfusions.

Figure 6
Responsiveness Quintile Changes in EPO and Transfusions Across the Bundle



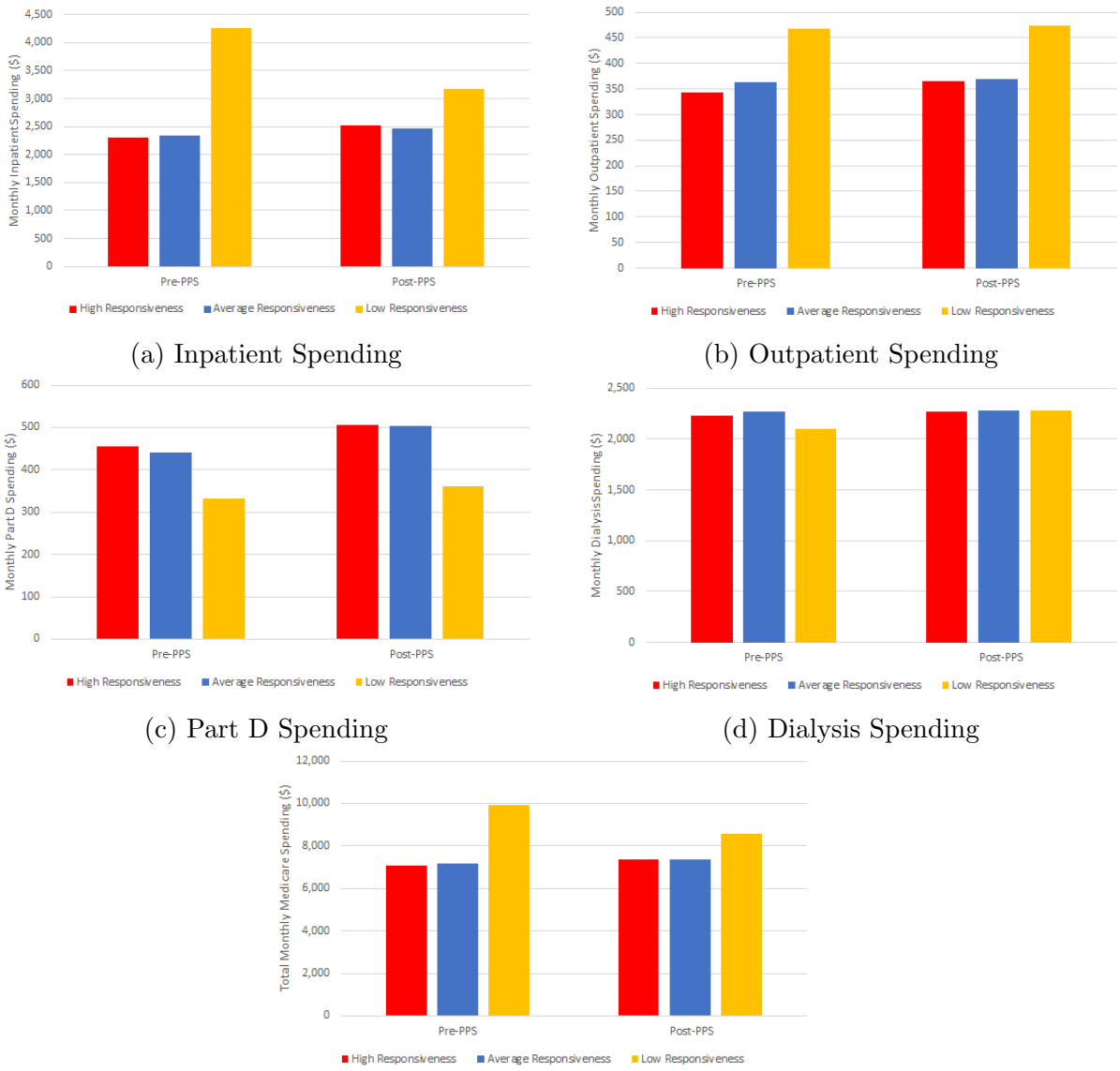
(a) EPO Dose



(b) Transfusion Rate

Notes: "High Responsiveness", "Average Responsiveness", and "Low Responsiveness" refer to patients with average estimated marginal effects of EPO on transfusions in the fifth, third, and first quintiles of absolute value, respectively. High-responsiveness patients have an average estimated marginal effect at least 0.73 standard deviations above the mean, while that of low-responsiveness patients is at least 0.78 standard deviations below the mean. Marginal effects are recovered from IV estimates of equation (6) using a series of dummy variables for each responsiveness quintile, with these estimates presented in Table A21. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 censored at the 99th percentile and measured in 1000 IUs.

Figure 7
Responsiveness Quintile Changes in Spending Across the Bundle: Spending



(a) Inpatient Spending

(b) Outpatient Spending

(c) Part D Spending

(d) Dialysis Spending

(e) Total Spending

Notes: "High Responsiveness", "Average Responsiveness", and "Low Responsiveness" refer to patients with average estimated marginal effects of EPO on transfusions in the fifth, third, and first quintiles of absolute value, respectively. High-responsiveness patients have an average estimated marginal effect at least 0.73 standard deviations above the mean, while that of low-responsiveness patients is at least 0.78 standard deviations below the mean. Marginal effects are recovered from IV estimates of equation (6) using a series of dummy variables for each responsiveness quintile, with these estimates presented in Table A23. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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.

Table 11
Difference in EPO Use and Health Outcomes by Patient Responsiveness to EPO & Chain Status

	(1) EPO	(2) EPO	(3) Transfusion	(4) Transfusion	(5) Mortality	(6) Mortality
Chain Ownership	10.57***	11.14***	-0.00128	-0.00117	-0.000309	0.0000169
	(1.768)	(1.771)	(0.00104)	(0.000985)	(0.000492)	(0.000446)
EPO-Responsiveness Z-Score	-0.533**	-1.072***	-0.0103***	-0.0104***	-0.00781***	-0.00784***
	(0.179)	(0.179)	(0.000356)	(0.000351)	(0.000253)	(0.000248)
EPO-Responsiveness Z-Score × Chain	-1.055***	-0.160	0.000585	0.000653+	-0.000528+	-0.000495+
	(0.218)	(0.218)	(0.000402)	(0.000395)	(0.000279)	(0.000272)
PPS	-2.748***		0.00504***		-0.000358	
	(0.719)		(0.000648)		(0.000383)	
PPS × Chain	-4.458***		-0.000268		0.000472	
	(0.753)		(0.000697)		(0.000414)	
EPO-Responsiveness Z-Score × PPS	0.699**	0.497*	0.00419***	0.00415***	0.00389***	0.00390***
	(0.231)	(0.241)	(0.000406)	(0.000404)	(0.000235)	(0.000234)
EPO-Responsiveness Z-Score × PPS × Chain	1.349***	1.139***	-0.0000172	-0.0000389	0.000658*	0.000656*
	(0.261)	(0.269)	(0.000454)	(0.000451)	(0.000265)	(0.000263)
Time Trend	-0.290***		-0.0000566*		-0.0000838***	
	(0.0254)		(0.0000243)		(0.0000157)	
Time Trend × Chain	-0.285***		-0.0000240		-0.0000309+	
	(0.0242)		(0.0000258)		(0.0000162)	
Facility Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1
R-squared	0.122	0.123	0.00916	0.00920	0.00484	0.00484
Dep. Var. Mean	48.50	48.50	0.0282	0.0282	0.0157	0.0157
Observations	10077264	10077264	10077264	10077264	10077264	10077264

Notes: OLS estimates from equation (8) with additional interactions with an indicator for chain ownership. Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are censored at the 99th percentile and measured in 1000 IUs. Dependent variables in columns (3)–(6) are binary outcome 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. EPO-Responsiveness 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 in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 them. 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 traditional fee-for-service reimbursements lead to wasted 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). Using a research design built around variation in EPO doses across high and low elevations, we show that allocative efficiency improved as result of a more comprehensive bundle. Other settings, like Medicare's bundled payments program for hip and knee replacements, have shown more modest reallocations (Einav et al., 2020b). As a chronic condition with potentially more scope for reducing the amount of resources used during a long course of treatment, dialysis providers may be more willing to adapt their practice styles in response to bundled payments. Moreover, Medicare's payment policies may also influence facilities' treatment of privately insured dialysis patients, as Einav et al. (2020a) found for lower extremity joint replacements.

Our results also highlight the potential for the effects of bundled payments to spill over from one provider to another. As we show here, dialysis facilities increased their profits by drastically cutting EPO doses, thereby shifting the costs of anemia management to others through an increase in transfusions. Likewise, facilities substituted vitamin D drugs for Cinacalcet, an oral drug covered outside the bundle under Medicare Part D. The specter of such spillovers should influence the design of future payment reforms like Medicare's Comprehensive ESRD Care Model, a voluntary program aimed at evaluating the merit and feasibility of ACO-style organizations for dialysis patients, as better understanding the global impact of similar payment schemes will remain an important area for future research.

References

Abaluck, J., L. Agha, C. Kabrhel, A. Raja, and A. Venkatesh (2016). The Determinants of Productivity in Medical Testing: Intensity and Allocation of Care. *American Economic Review 106*, 3730–3764.

Acemoglu, D. and A. Finkelstein (2008). Input and Technology Choices in Regulated Industries: Evidence from the Health Care Sector. *Journal of Political Economy 116*, 837–880.

Agarwal, R., J. M. Liao, A. Gupta, and A. S. Navathe (2020). The Impact of Bundled Payment on Health Care Spending, Utilization, and Quality: A Systematic Review. *Health Affairs 39*(1), 50–57.

Babitt, J. L. and H. Y. Lin (2006). Mechanisms of Anemia in CKD. *Journal of the American Society of Nephrology 23*, 1631–1634.

Bach, P. B. (2009). Limits on Medicare's Ability to Control Rising Spending on Cancer Drugs. *The New England journal of medicine 360*(6), 626–633.

Baicker, K., A. Chandra, and J. S. Skinner (2012). Saving money or just saving lives? improving the productivity of us health care spending. *Annual Review of Economics 4*(1), 33–56.

Baicker, K. and T. Svoronos (2019). Testing the Validity of the Single Interrupted Time Series Design. *NBER Working Paper 26080*.

Bain, B. J., I. Bates, and M. A. Laffan (2017). *Dacie and Lewis Practical Haematology* (12 ed.).

Baker, S. (2019). The U.S. Health Care System is Full of Monopolies. *Axios*.

Barnett, M. L., A. Wilcock, J. M. McWilliams, A. M. Epstein, K. E. Joynt Maddox, E. J. Orav, D. C. Grabowski, and A. Mehrotra (2019). Two-year Evaluation of Mandatory Bundled Payments for Joint Replacement. *New England Journal of Medicine 380*(3), 252–262.

Bekelman, J. E., A. Gupta, E. Fishman, D. J. Debono, M. J. Fisch, Y. Liu, G. Sylwestrzak, J. Barron, and A. S. Navathe (2020). Association between a national insurer's pay-for-performance program for oncology and changes in prescribing of evidence-based cancer drugs and spending. *Journal of Clinical Oncology 38*(15_suppl), 2016–2016.

Bertuzzi, L., P. J. Eliason, B. Heebsh, R. League, R. C. McDevitt, and J. W. Roberts (2021). Strategic Patient Dropping. Working Paper.

Besarab, A., W. Bolton, J. E. J. Browne, A. Nissenson, D. Okamoto, S. Schwab, and D. Goodkin (1998, August). The Effects of Normal as Compared with Low Hematocrit Values in Patients with Cardiac Disease Who Are Receiving Hemodialysis and Epoetin. *The New England Journal of Medicine 339*, 584–590.

Bettinger, E. P., L. Fox, S. Loeb, and E. S. Taylor (2017). Virtual Classrooms: How Online College Courses Affect Student Success. *American Economic Review 107*(9), 2855–2875.

Bhan, I. and R. Thadhani (2009). Vitamin d therapy for chronic kidney disease. *Seminars in Nephrology 29*(1), 85–93. Nutrition in Kidney Disease.

Bradbury, B. D., M. D. Danese, M. Gleeson, and C. W. Critchlow (2009). Effect of Epoetin Alpha Dose Changes on Hemoglobin and Mortality in Hemodialysis Patients with Hemoglobin Levels Persistently below 11g/dL. *Clinical Journal of the American Society of Nephrology 4*, 630–637.

Brookhart, M., S. Schneeweiss, J. Avorn, B. Bradbury, J. Liu, and W. Winkelmayer (2010, March). Comparative Mortality Risk of Anemia Management Practices in Incident Hemodialysis Patients. *Journal of the American Medical Association 303*(9), 857–864.

Brookhart, M. A., B. D. Bradbury, J. Avorn, S. Schneeweiss, and W. C. Winkelmayer (2011). The Effect of Altitude on Anemia Treatment Responses in Hemodialysis Patients. *American Journal of Epidemiology 173*, 768–777.

Brookhart, M. A., S. Schneeweiss, J. Avorn, B. D. Bradbury, K. J. Rothman, M. Fischer, J. Mehta, and W. C. Winkelmayer (2008). The Effect of Altitude on Dosing and Response to Erythropoietin in ESRD. *Journal of the American Society of Nephrology*, 1389–1395.

Brot-Goldberg, Z. C., A. Chandra, B. R. Handel, and J. T. Kolstad (2017, 04). What does a Deductible Do? The Impact of Cost-Sharing on Health Care Prices, Quantities, and Spending Dynamics. *The Quarterly Journal of Economics 132*(3), 1261–1318.

Card, D. (1995). *Aspects of Labour Market Behavior: Essays in Honor of John Vanderkamp*, Chapter Using Geographic Variation in College Proximity to Estiamte the Return to Schooling. Toronto: University of Toronto Press.

Chan, D. C., M. Gentzkow, and C. Yu (2019). Selection with Variation in Diagnostic Skill: Evidence from Radiologists. *NBER Working Paper No. 26467*.

Chandra, A. and D. Staiger (2017). Identifying Sources of Inefficiency in Health Care. *NBER Working Paper 24035*.

Chertow, G., J. Liu, K. Monda, D. Gilbertson, M. Brookhard, A. Beaurbrun, W. Winkelmayer, A. Pollock, C. Herzog, A. Ashfaq, T. Sturmer, K. Rothman, B. Bradbury, and A. Collins (2016). Epoetin Alfa and Outcomes in Dialysis amid Regulatory and Payment Reform. *Journal of the American Society of Nephrology 27*, 3129–3138.

Christian, P. and C. Barrett (2017). Revisiting the Effect of Food Aid on Conflict: A Methodological Caution. *World Bank Policy Research Working Paper No. 8171*.

Clemens, J. and J. Gottlieb (2014). Do Physicians' Financial Incentives Affect Medical Treatment and Patient Health? *American Economic Review 104*(4), 1320–1349.

Currie, J. and W. B. MacLeod (2013). Diagnosis and Unnecessary Procedure Use: Evidence from C-Section. *NBER Working Paper 18977*.

Cutler, D. (1995). The Incidence of Adverse Medical Outcomes Under Prospective Payment. *Econometrica 63*, 29–50.

Cutler, D., L. Dafny, and C. Ody (2017). How Does Competition Impact the Quality of Price of Outpatient Service Facilities? A Case Study of the U.S. Dialysis Industry. Working Paper.

Cutler, D. and K. Ghosh (2012). The potential for cost savings through bundled episode payments. *New England Journal of Medicine 366*(12), 1075–1077.

Dafny, L. (2005). How Do Hospitals Respond to Price Changes. *American Economic Review 95*, 1525–1547.

Dai, M. (2014). Product Choice Under Price Regulation: Evidence from Out-Patient Dialysis Markets. *International Journal of Industrial Organization 32*, 24–32.

Dai, M. and X. Tang (2015). Regulation and Capacity Competition in Health Care: Evidence from US Dialysis Markets. *The Review of Economics and Statistics 97*(5), 965–982.

DaVita (2005, May). DaVita 2004 Annual Report.

Dummit, L. A., D. Kahvecioglu, G. Marrufo, R. Rajkumar, J. Marshall, E. Tan, M. J. Press, S. Flood, L. D. Muldoon, Q. Gu, A. Hassol, D. M. Bott, A. Bassano, and P. H. Conway (2016, 09). Association Between Hospital Participation in a Medicare Bundled Payment Initiative and Payments and Quality Outcomes for Lower Extremity Joint Replacement Episodes. *JAMA 316*(12), 1267–1278.

Einav, L., A. Finkelstein, Y. Ji, and N. Mahoney (2020a). Randomized Trial Shows Healthcare Payment Reform Has Equal-sized Spillover Effects on Patients Not Targeted by Reform. *Proceedings of the National Academy of Sciences 117*(32), 18939–18947.

Einav, L., A. Finkelstein, Y. Ji, and N. Mahoney (2020b). Voluntary Regulation: Evidence from Medicare Payment Reform. Technical report, National Bureau of Economic Research.

Einav, L., A. Finkelstein, and N. Mahoney (2018). Provider Incentives and Healthcare Costs: Evidence from Long-Term Care Hospitals. *Econometrica 86*(6), 2161–2219.

Eliason, P. (2021). Price Regulation and Market Structure: Evidence from the Dialysis Industry. Working Paper.

Eliason, P. J., P. L. Grieco, R. C. McDevitt, and J. W. Roberts (2018). Strategic Patient Discharge: The Case of Long-Term Care Hospitals. *American Economic Review 108*(11), 3232–65.

Eliason, P. J., B. Heebsh, R. C. McDevitt, and J. W. Roberts (2020). How Acquisitions Affect Firm Behavior and Performance: Evidence from the Dialysis Industry. *The Quarterly Journal of Economics 135*(1), 221–267.

Eschbach, J. W., M. H. Abdulhadi, J. K. Browne, B. G. Delano, M. R. Downing, J. C. Egrie, R. W. Evans, E. A. Friedman, S. E. Graber, and N. R. Haley (1989). Recombinant human erythropoietin in anemic patients with end-stage renal disease. results of a phase iii multicenter clinical trial. *Annals of internal medicine 111 12*, 992–1000.

Finkelstein, A., Y. Ji, N. Mahoney, and J. Skinner (2018, 09). Mandatory Medicare Bundled Payment Program for Lower Extremity Joint Replacement and Discharge to Institutional Postacute Care: Interim Analysis of the First Year of a 5-year Randomized Trial. *JAMA 320*(9), 892–900.

Frank, R. G. and R. J. Zeckhauser (2007). Custom-made versus ready-to-wear treatments: Behavioral propensities in physicians' choices. *Journal of Health Economics 26*(6), 1101–1127.

French, H., C. Whaley, B. Handel, L. Bowers, C. SImon, and R. Scheffler (2015). Market Power, Transaction Costs, and the Entry of Accountable Care Organizations in Health Care. *Review of Industrial Organization 47*, 167–193.

Garber, A. M. and J. Skinner (2008). Is American Health Care Uniquely Inefficient? *Journal of Economic Perspectives 22*(4), 27–50.

Gaynor, M., N. Mehta, and S. Richards-Shubik (2020). Optimal Contracting with Altruistic Agents: A Structural Model of Medicare Reimbursements for Dialysis Drugs. Working Paper.

Glied, S. and A. Sacarny (2018, 10). Is the US Health Care System Wasteful and Inefficient? A Review of the Evidence. *Journal of Health Politics, Policy and Law 43*(5), 739–765.

Grieco, P. and R. C. McDevitt (2017). Productivity and Quality in Health Care: Evidence from the Dialysis Industry. *The Review of Economic Studies 84*(3), 1071–1105.

Hirth, R., M. Turenne, A. Wilk, J. Wheeler, K. Sleeman, W. Zhang, M. Paul, T. Nahra, and J. Messana (2014). Blood Transfusion Practices in Dialysis Patients in a Dynamic Regulatory Environment. *American Journal of Kidney Disease 64*, 616–621.

Kalantar-Zadeh, K. (2017). History of Erythropoiesis-Stimulating Agents, the Development of Biosimilars, and the Future of Anemia Treatment in Nephrology. *American Journal of Nephrology 45*, 235–247.

Kliger, A. S., R. N. Foley, D. S. Goldfarb, S. L. Goldstein, K. Johansen, A. Singh, and L. Szczech (2013, November). KDOQI US Commentary on the 2012 KDIGO Clinical Practice Guideline for Anemia in CKD. journal article.

League, R., P. J. Eliason, R. C. McDevitt, J. W. Roberts, and H. Wong (2021). High Prices and Wide Dispersion in Private Insurance Payments for Dialysis. Working Paper.

Lin, E. (2021, 03). The Cost of Transferring Dialysis Care From the Employer-Based Market to Medicare. *JAMA Network Open 4*(3), e212113–e212113.

Lin, E. and S. Watnick (2019). Calcimimetics and bundled reimbursement. *American Journal of Kidney Diseases 73*(3), 385–390.

Martin, B. I., J. D. Lurie, F. R. Farrokhi, K. J. McGuire, and S. K. Mirza (2018). Early Effects of Medicare's Bundled Payment for Care Improvement Program for Lumbar Fusion. *Spine 43*, 705–711.

Maughan, B. C., D. C. Kahvecioglu, G. Marrufo, G. M. Gerding, S. Dennen, J. K. Marshall, D. M. Cooper, C. M. Kummet, and L. A. Dummit (2019). Medicare's Bundled Payments For Care Improvement Initiative Maintained Quality Of Care For Vulnerable Patients. *Health Affairs 38*(4), 561–568.

McWilliams, J. M., L. Hatfield, B. Landon, and M. Chernew (2020). Savings or Selection? Initial Spending Reductions in the Medicare Shared Savings Program and Considerations for Reform. *Milbank Quarterly 98*(3), 847–907.

MEDPAC (2017, June). Report to Congress: Medicare and the Health Care Delivery System. Technical report, Medicare Payment Advisory Commission, Washington, DC.

Navathe, A. S., A. B. Troxel, J. M. Liao, N. Nan, J. Zhu, W. Zhong, and E. J. Emanuel (2017, 02). Cost of Joint Replacement Using Bundled Payment Models. *JAMA Internal Medicine 177*(2), 214–222.

Nunn, N. and N. Qian (2014). US Food Aid and Civil Conflict. *American Economic Review 104*(6), 1630–1666.

Nyweide, D., W. Lee, T. Cuerdon, H. Pham, M. Cox, R. Rajkumar, and P. Conway (2015). Association of Pioneer Accountable Care Organizations vs Traditional Medicare Fee for Service with Spending, Utilization, and Patient Experience. *JAMA 313*(21), 2152–2161.

Pozniak, A. S., R. A. Hirth, J. Banaszak-Holl, and J. R. Wheeler (2010). Predictors of Chain Acquisition Among Independent Dialysis Facilities. *Health services research 45*(2), 476–496.

Rolnick, J. A., J. M. Liao, E. J. Emanuel, Q. Huang, X. Ma, E. Z. Shan, C. Dinh, J. Zhu, E. Wang, D. Cousins, et al. (2020). Spending and Quality after Three Years of Medicare's Bundled Payments for Medical Conditions: Quasi-experimental Difference-in-differences Study. *bmj 369*.

Shatto, J. D. (2016). Center for Medicare and Medicaid Innovation's Methodology and Calculations for the 2016 Estimate of Fee-For-Service Payments to Alternative Payment Models. *Centers for Medicare and Medicaid Services*.

Sibbel, S., B. J. Maroni, and S. M. Brunelli (2017). The Effect of Altitude on Erythropoiesis-Stimulating Agent Dose, Hemoglobinn Level, and Mortality in Hemodialysis Patients. *Journal of Nephrology 30*, 821–829.

Singh, A., L. Szczech, K. Tang, H. Barnhart, S. Sapp, M. Wolfson, and D. Reddan (2006, November). Correction of Anemia with Epoeitin Alfa in Chronic Kidney Disease. *The New England Journal of Medicine 355*, 2085–2098.

Sloan, F., M. Morrisey, and J. Valvona (1988a). Case Shifting and the Medicare Prospective Payment System. *American Journal of Public Health 78*, 553–556.

Sloan, F., M. Morrisey, and J. Valvona (1988b). Effects of Medicare Prospective Payment System on Hospital Cost Containment: An Early Appraisal. *The Milbank Quarterly 66*, 191–220.

Thamer, M., Y. Zhang, D. Lai, O. Kshirsagar, and D. Cotter (2013). Influence of Safety Warnings on ESA Prescribing among Dialysis Patients Using an Interrupted Time Series. *BMC Nephrology 14*.

United States Renal Data System (2014). 2014 USRDS Annual Data Report: Epidemiology of Kidney Disease in the United States. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases.

United States Renal Data System (2019). USRDS 2019 Annual Data Report: Epidemiology of Kidney Disease in the United States. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases.

U.S. Geological Survey Center for Earth Resources Observation and Science (2014). GTOPO30 Global 30 Arc-Second Elevation.

U.S. Government Accountability Office (2012, October). Medicare Part B Drug Spending. Publication No. GAO-13-46R, Retrieved from `https://www.gao.gov/assets/650/649459.pdf`.

Valderrabano, F. (2000). Quality of Life Benefits of Early Anemia Treatment. *Nephrology Dialysis Transplant 15*, 23–28.

Wang, V., C. Coffman, L. Sanders, S. Lee, R. Hirth, and M. Maciejewski (2018). Medicare's New Prospective Payment System on Facility Provision of Peritoneal Dialysis. *Clinical Journal of the American Society of Nephrology 13*, 1833–1841.

Whoriskey, P. (2012, August). Medicare Overspending on Anemia Drug. *Washington Post*.

Wilson, N. E. (2016a). For-Profit Status and Industry Evolution in Health Care Markets: Evidence from the Dialysis Industry. *International Journal of Health Economics and Management 16*(4), 297–319.

Wilson, N. E. (2016b). Market Structure as a Determinant of Patient Care Quality. *American Journal of Health Economics 2*(2), 241–271.

Winkelmayer, W. C., J. Lui, and M. A. Brookhart (2009). Altitude and All-Cause Mortality in Incident Dialysis Patients. *Journal of the American Medical Association 305*.

Zhang, Q., M. Thamer, O. Kshirsagar, and Y. Zhang (2017). Impact of the end stage renal disease prospective payment system on the use of peritoneal dialysis. *Kidney International Reports 2*(3), 350–358.

Zhang, Y., M. Thamer, K. Stefanik, J. Maukman, and D. Cotter (2004). Epoeitin Requirements Predict Mortality in Hemodialysis Patients. *American Journal of Kidney Disease 45*, 866–876.

Appendix: For Online Publication

The following appendices provide additional robustness checks, analyses, and details on our data.

Appendix A shows that neither the black box warnings nor the QIP can explain the patterns we observe for EPO doses.

Appendix B contains additional summary statistics by quintile of facility elevation.

Appendix C shows that our results are robust to a possible anticipatory response by providers.

Appendix D gives details on the supply agreements between dialysis chains and Amgen.

Appendix E presents additional time series results.

Appendix F repeats the exercise from Section 5 using equation (6) to estimate the effect of EPO on patients' HGB levels.

Appendix G contains additional tables and figures referenced in Section 5.

Appendix H describes other channels through which the bundle may have affected patients.

Appendix I illustrates the robustness of our results to differences in the timing of PPS adoption.

A. The Effect of Black Box Warnings & QIP on EPO

Although the FDA's updated black box warning for EPO and Medicare's introduction of the QIP for dialysis facilities occurred around the same time as the payment reform, we present evidence that neither contributes meaningfully to the decline in EPO doses shown in the paper. For the black box warning, four institutional details suggest that it did not cause the decrease in EPO around 2011. First, we show in Appendix H that other injectable drugs, which did not receive black box warnings, follow a pattern similar to EPO's after the bundle. Second, as we discuss in Section 2.2, the FDA has issued two black box warnings for EPO, both of which recommend providers use EPO more judiciously, but the evolution of EPO doses in Figure A1 shows that they did not change following the first black box warning in 2007, an instance when the label changed but financial incentives did not. Third, the decline in EPO begins in October 2010, eight months before the black box warning update, and it is unclear why providers would have changed their behavior in anticipation of the new black box warning even if they had been aware of the FDA's looming decision given that they did not change their behavior following the first black box warning. Finally, in Appendix D we show that a coincidental drop in EPO stems from one large chain that renegotiated its contract with drug supplier Amgen in mid-2011, as other chains and independent facilities do not exhibit the same patterns for EPO doses.

The other policy change around the start of the bundle was the QIP. As we explain in Section 2.5, Medicare instituted the QIP along with bundled payments to provide facilities with incentives for maintaining high-quality care while still restraining reimbursement costs. In contrast to the PPS that focuses on cost containment, the QIP aims to promote a high standard of care by reducing payments to poorly performing facilities.

To implement the QIP, each year Medicare announces the various performance measures that will comprise a facility's Total Performance Score (TPS). Facilities whose scores fall short of the benchmark that year face a reduction of their Medicare reimbursements of between 0.5–2.0%, depending on the extent of the shortfall. During the sample period for our paper, Medicare used three clinical measures to construct the TPS: the percentage of patients with (i) HGB below 10 g/dL, (ii) HGB above 12g/dL, and (iii) URR above 0.65. For the first year of the QIP in 2012, Medicare used the facility's performance on these measures in 2010 to construct the TPS. For 2013 and 2014, only the latter two measures were used (based on facility performance in 2011 and 2012, respectively), with Medicare dropping low HGB

levels as a criteria. The QIP also included a measure of vascular access in the TPS for 2014, although vascular access has no relation to EPO or other injectable drugs included in the payment reform, so we do not discuss it here.

Although Medicare introduced the QIP to discipline facilities' behavior, Figures A2a and A2b show that it did not cause the decline in EPO doses during this period — if anything, the QIP likely makes our estimate of the bundle's impact on EPO doses a conservative one. In Figure A2a, which shows the percentage of patients with HGB greater than 12 g/dL, we see no change in trend following the announcement of this performance measure in 2010. Because EPO directly affects patients' HGB levels, the fact that the trend in the proportion of patients with high HGB levels remained constant after facilities began receiving penalties suggests this standard had little impact on dosing decisions.

Figure A2b shows the percentage of patients with HGB less than 10 g/dL.[26] Again, facilities did not respond to the metric's introduction, with the trend remaining constant throughout 2010, although we do see evidence consistent with facilities responding to the metric's removal in 2011. The sharp rise in patients with HGB less than 10 g/dL after Medicare removed this metric from the QIP suggests that (i) our estimates of the bundle's impact on EPO and outcomes are potentially understated, because facilities may have continued giving EPO to low-HGB patients to avoid QIP penalties, and (ii) direct financial incentives from reimbursements predominately dictate facilities' dosing decisions, as facilities cut EPO doses to reduce their drug costs immediately upon Medicare's removal of the low-HGB guardrails.

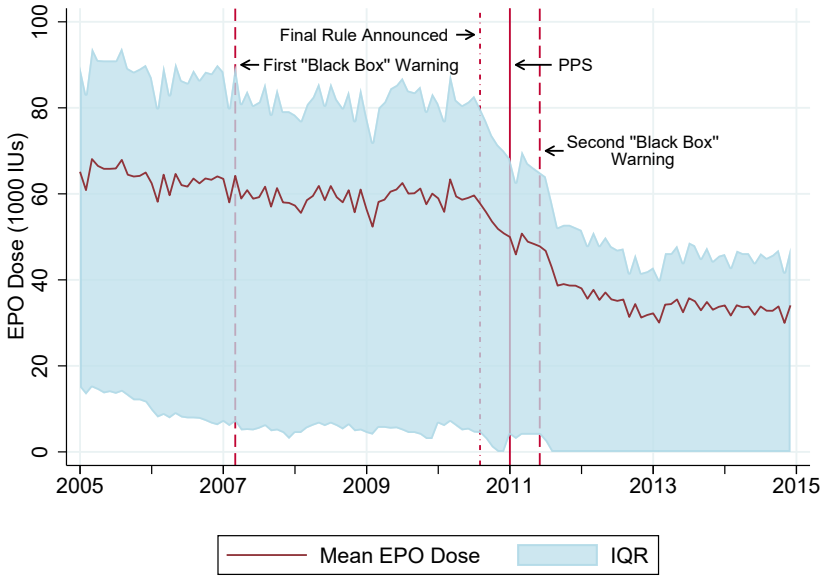
As a final piece of evidence that the QIP did not drive dosing decisions, we point to the way facilities treated EPO-unresponsive patients after the bundle was introduced. Independent of any HGB criteria from the QIP, facilities cut EPO doses the most for patients whose blood levels did not change in response to EPO, as we show in Section 5 and Appendix F. By concentrating the cuts in EPO on patients whose blood levels would remain unaffected, facilities revealed that reducing drug costs rather than avoiding QIP penalties precipitated their treatment decisions.

In short, although the black box warning in 2011 and the QIP performance measures applied to 2010–2012 could have potentially confounded our analysis of the payment reform's effect on EPO doses, we find little evidence that they did, and, if anything, they suggest our results may be conservative.

[26]The removal of the measure relating to the percentage of patients with HGB below 10 g/dL was announced in July 2011 and retroactively applied to the performance year beginning January 2011. This means that the TPS calculated using facilities' performances from January to December of 2011 did not include the percentage of patients with HGB below 10 g/dL, but facilities did not learn that this measure would not be used until midway through the year. This proposed rule change was finalized by Medicare in November 2011.

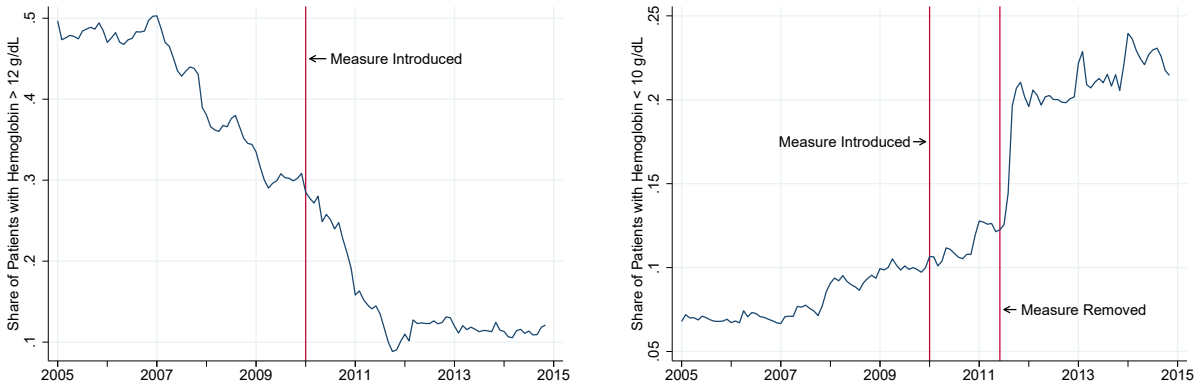
Moreover, because Medicare introduced the QIP in conjunction with the PPS, any potential confounding from the QIP would simply add nuance to our interpretation of the reforms rather than undermine our main findings. That is, we find that the financial incentives from the payment reform had a much stronger influence on facility behavior than the penalties from the QIP did, which provides valuable insights to policy makers aiming to restrain reimbursement costs while maintaining high standards for care. We consider the full effects of the QIP in Bertuzzi et al. (2021).

Figure A1
Monthly EPO Doses Over Time with Black Box Warnings



Notes: An observation is a patient-month. Sample consists of observations from January 2005 to December 2014 for in-center 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 censored at the 99th percentile and measured in 1000 IUs. Vertical long-dashed lines indicate the release of official warnings from the FDA about the safety of high EPO doses. The solid vertical line indicates the start of PPS in January 2011, while the dot-dashed vertical line indicates the announcement of the final rule for PPS.

Figure A2
QIP HGB Performance Measures



(a) HGB > 12 g/dL Over Time

(b) HGB < 10 g/dL Over Time

Notes: 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 2005 to December 2014 for in-center 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. Vertical lines indicate the introduction and removal of the QIP performance measure.

B. 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 somewhat 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 that 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	Total
Patient Characteristics						
Predicted Mortality	0.016	0.015	0.016	0.017	0.017	0.016
Age (Years)	63.41	63.60	62.91	63.53	63.57	63.40
Months with ESRD	45.59	45.35	45.72	45.49	43.22	45.08
Black	0.447	0.440	0.452	0.375	0.211	0.385
Male	0.553	0.548	0.545	0.551	0.562	0.552
Diabetic	0.526	0.534	0.536	0.544	0.560	0.540
Hypertensive	0.910	0.906	0.909	0.905	0.900	0.906
Incident Hemoglobin	9.755	9.786	9.806	9.901	10.018	9.853
Facility Characteristics						
Facility Elevation (ft)	29.4	143.7	436.1	713.5	1875.9	638.1
Independent Ownership	0.185	0.183	0.177	0.231	0.208	0.197
Resource Use						
EPO Dose (1000 IUs)	51.50	50.24	50.94	46.84	42.90	48.50
Receives Any EPO	0.791	0.784	0.779	0.725	0.694	0.755
Medicare Spending ($)						
Total	8,019	8,042	7,342	7,389	6,980	7,555
Inpatient	2,788	2,759	2,443	2,469	2,328	2,558
Dialysis	2,320	2,372	2,266	2,262	2,215	2,287
Part D	499	493	464	442	428	465
Outpatient	352	389	410	424	394	394
Health Outcomes						
Hemoglobin (g/dL)	11.11	11.11	11.12	11.12	11.16	11.12
Mortality	0.015	0.015	0.015	0.016	0.017	0.016
Hospitalizations						
Any Cause	0.1406	0.1382	0.1355	0.1418	0.1340	0.1380
Cardiac Event	0.0280	0.0281	0.0268	0.0280	0.0248	0.0271
Septicemia	0.0097	0.0095	0.0091	0.0095	0.0090	0.0094
Transfusions						
Total	0.0297	0.0282	0.0278	0.0281	0.0270	0.0282
Inpatient	0.0255	0.0242	0.0226	0.0225	0.0210	0.0232
Outpatient	0.0047	0.0045	0.0059	0.0064	0.0068	0.0057
Emergency Room	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Unique Patients	102,897	99,507	102,182	103,307	103,770	461,477
Patient-Months	2,043,637	1,989,978	2,033,229	2,000,408	2,010,037	10,077,289

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 using coefficents from a regression of mortality on patient controls and time fixed effects on observations from 2009 and 2010. 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 censored at the 99th percentile and measured in 1000 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, 2009

	Elevation Quintile					
	First	Second	Third	Fourth	Fifth	Total
Patient Characteristics						
Predicted Mortality	0.016	0.015	0.016	0.017	0.017	0.016
Age (Years)	63.44	63.57	62.98	63.65	63.83	63.49
Months with ESRD	42.29	42.25	42.39	42.53	40.03	41.90
Black	0.446	0.438	0.447	0.370	0.207	0.382
Male	0.550	0.546	0.543	0.549	0.559	0.549
Diabetic	0.510	0.524	0.524	0.531	0.549	0.528
Hypertensive	0.908	0.905	0.910	0.904	0.899	0.905
Incident Hemoglobin	9.836	9.855	9.866	9.975	10.094	9.925
Facility Characteristics						
Facility Elevation (ft)	29.8	143.3	437.8	714.2	1868.8	638.0
Independent Ownership	0.199	0.202	0.195	0.267	0.229	0.218
Resource Use						
EPO Dose (1000 IUs)	63.28	61.73	62.19	55.73	52.35	59.07
Receives Any EPO	0.813	0.802	0.795	0.732	0.713	0.771
Medicare Spending ($)						
Total	8,016	7,999	7,305	7,299	6,801	7,483
Inpatient	2,846	2,818	2,492	2,520	2,320	2,599
Dialysis	2,283	2,326	2,236	2,211	2,145	2,240
Part D	442	445	417	394	382	416
Outpatient	332	364	377	387	361	364
Health Outcomes						
Hemoglobin (g/dL)	11.46	11.45	11.44	11.45	11.46	11.45
Mortality	0.016	0.016	0.017	0.018	0.017	0.017
Hospitalizations						
Any Cause	0.1471	0.1446	0.1420	0.1463	0.1391	0.1438
Cardiac Event	0.0307	0.0303	0.0289	0.0300	0.0267	0.0293
Septicemia	0.0093	0.0091	0.0088	0.0089	0.0084	0.0089
Transfusions						
Total	0.0256	0.0249	0.0247	0.0256	0.0244	0.0250
Inpatient	0.0219	0.0211	0.0201	0.0203	0.0188	0.0205
Outpatient	0.0042	0.0042	0.0051	0.0059	0.0063	0.0051
Emergency Room	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Unique Patients	54,576	52,150	54,661	53,701	54,001	256,504
Patient-Months	477,695	457,844	478,139	467,866	468,898	2,350,442

Notes: An observation is a patient-month. Sample consists of observations from January to December 2009 for in-center 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 using coefficents from a regression of mortality on patient controls and time fixed effects on observations from 2009 and 2010. 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 censored at the 99th percentile and measured in 1000 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, 2012

	Elevation Quintile					
	First	Second	Third	Fourth	Fifth	Total
Patient Characteristics						
Predicted Mortality	0.016	0.016	0.016	0.017	0.017	0.016
Age (Years)	63.37	63.63	62.85	63.35	63.33	63.31
Months with ESRD	48.98	48.68	49.02	48.59	46.44	48.34
Black	0.448	0.443	0.454	0.379	0.213	0.388
Male	0.556	0.551	0.546	0.554	0.565	0.554
Diabetic	0.538	0.542	0.546	0.555	0.569	0.550
Hypertensive	0.911	0.908	0.909	0.906	0.902	0.907
Incident Hemoglobin	9.664	9.710	9.737	9.819	9.935	9.772
Facility Characteristics						
Facility Elevation (ft)	29.2	144.3	434.4	713.6	1886.7	637.2
Independent Ownership	0.172	0.161	0.150	0.197	0.184	0.173
Resource Use						
EPO Dose (1000 IUs)	36.71	36.11	36.75	34.27	30.43	34.87
Receives Any EPO	0.759	0.761	0.751	0.708	0.662	0.728
Medicare Spending ($)						
Total	7,884	7,890	7,224	7,290	6,959	7,453
Inpatient	2,637	2,564	2,277	2,301	2,196	2,397
Dialysis	2,390	2,456	2,334	2,353	2,322	2,371
Part D	571	550	523	499	480	525
Outpatient	373	417	441	463	427	424
Health Outcomes						
Hemoglobin (g/dL)	10.79	10.81	10.82	10.83	10.89	10.83
Mortality	0.015	0.014	0.015	0.015	0.015	0.015
Hospitalizations						
Any Cause	0.1344	0.1305	0.1283	0.1348	0.1275	0.1311
Cardiac Event	0.0257	0.0258	0.0246	0.0256	0.0227	0.0249
Septicemia	0.0103	0.0100	0.0094	0.0099	0.0094	0.0098
Transfusions						
Total	0.0326	0.0302	0.0296	0.0298	0.0288	0.0302
Inpatient	0.0279	0.0257	0.0236	0.0234	0.0221	0.0246
Outpatient	0.0053	0.0051	0.0067	0.0072	0.0075	0.0064
Emergency Room	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Unique Patients	60,055	58,219	58,652	58,026	58,970	280,751
Patient-Months	543,541	528,788	531,440	518,537	527,525	2,649,831

Notes: An observation is a patient-month. Sample consists of observations from January to December 2012 for in-center 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 using coefficents from a regression of mortality on patient controls and time fixed effects on observations from 2009 and 2010. 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 censored at the 99th percentile and measured in 1000 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.

C. Potential Anticipatory Responses

Given the difficulty of changing clinical practices, we may expect them to change gradually and in anticipation of the bundle. Indeed, in Figure 3, among others, we see that EPO doses began to decrease in mid-2010, prior to the bundle's start in January 2011. In this appendix, we both quantify these anticipatory effects and show that our results are robust to including this period of anticipatory responses by providers in the post-bundle period.

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

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

where $\bar{Y}_t$ is the mean EPO dose in month t and X_t is a series of month-of-year fixed effects. We estimate this equation using only data from January 2005 through December 2009 and then use the estimated coefficients to calculate the predicted level of EPO for each month in 2010 and 2011. From the predicted and observed values in Table A4, we find that the first month in which the realized mean EPO dose is below the predicted level is October 2010, and that this drop continues to grow through 2011.

We corroborate our finding that the anticipatory response began in October 2010 by using a falsification test from Baicker and Svoronos (2019). To do so, 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. From this, October 2010 returns the highest Wald statistic, 267, suggesting it is the most likely month of a structural break in the trend in EPO doses, which would indicate an anticipation of the bundle by providers.

In light of a possible anticipatory response, we consider the robustness of our main findings to this anticipation. In particular, we recreate the tables and figures presented in the main text while treating the start date of the bundle as October 2010 rather than the actual start date of January 2011. In this way, we treat the period during which facilities were modifying their behavior in anticipation of the bundle as part of the treatment period. Tables A5–A10 and Figure A3 recreate our main results and show that they are robust to this alternative definition of the bundle period.

Table A4
Difference in EPO Relative to Trend

	Actual	Predicted	Difference
2010			
January	58.95	56.19	2.76
February	55.81	52.28	3.53
March	63.36	57.90	5.46
April	59.39	55.96	3.43
May	58.64	58.08	0.56
June	59.06	56.60	2.46
July	59.63	57.64	1.99
August	57.76	57.76	0.00
September	55.77	55.77	0.00
October	53.57	57.61	-4.04
November	51.85	55.03	-3.17
December	50.80	56.94	-6.14
2011			
January	49.98	54.64	-4.66
February	45.90	50.72	-4.82
March	50.77	56.34	-5.57
April	48.88	54.41	-5.52
May	48.36	56.52	-8.16
June	47.80	55.04	-7.25
July	46.74	56.09	-9.35
August	42.97	56.20	-13.24
September	38.66	54.21	-15.55
October	39.01	56.05	-17.03
November	38.68	53.47	-14.79
December	38.65	55.39	-16.74

Notes: Predicted values from OLS estimate of equation (9). Dependent variable is monthly EPO dose. EPO doses are censored at the 99th percentile and measured in 1000 IUs. An observation is a patient-month. Estimation sample consists of observations from January 2005 to December 2009 for in-center 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. Sample presented in table consist of analogous observations from January 2010 to December 2011.

Table A5
Effect of Bundle on EPO Dose

	(1) EPO	(2) EPO	(3) EPO	(4) EPO
PPS	-19.45***	-21.10***	-18.15***	-5.132***
	(0.246)	(0.237)	(0.421)	(0.226)
Pat/Fac Controls	0	1	1	1
Facility FE	0	0	1	1
Patient FE	0	0	0	1
Dep. Var. Mean	47.04	47.04	47.04	47.08
R-squared	0.0239	0.0804	0.134	0.532
Observations	10157714	10157714	10157683	10139936

Notes: OLS estimates from equation (1). Dependent variable is monthly EPO dose. EPO doses are censored at the 99th percentile and measured in 1000 IUs. 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 in-center 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 is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 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 (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 October 2010 or later. An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for in-center 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 is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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
The Effect of EPO on Health Outcomes

	HGB		Transfusion	
	(1) OLS	(2) IV	(3) OLS	(4) IV
EPO	-0.00283***	0.0161***	0.000125***	-0.000568***
	(0.0000248)	(0.00454)	(0.00000250)	(0.000146)
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		37.93		55.76

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 censored at the 99th percentile and measured in 1000 IUs. An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for in-center 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 is freestanding or hospital-based, and chain ownership, 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.

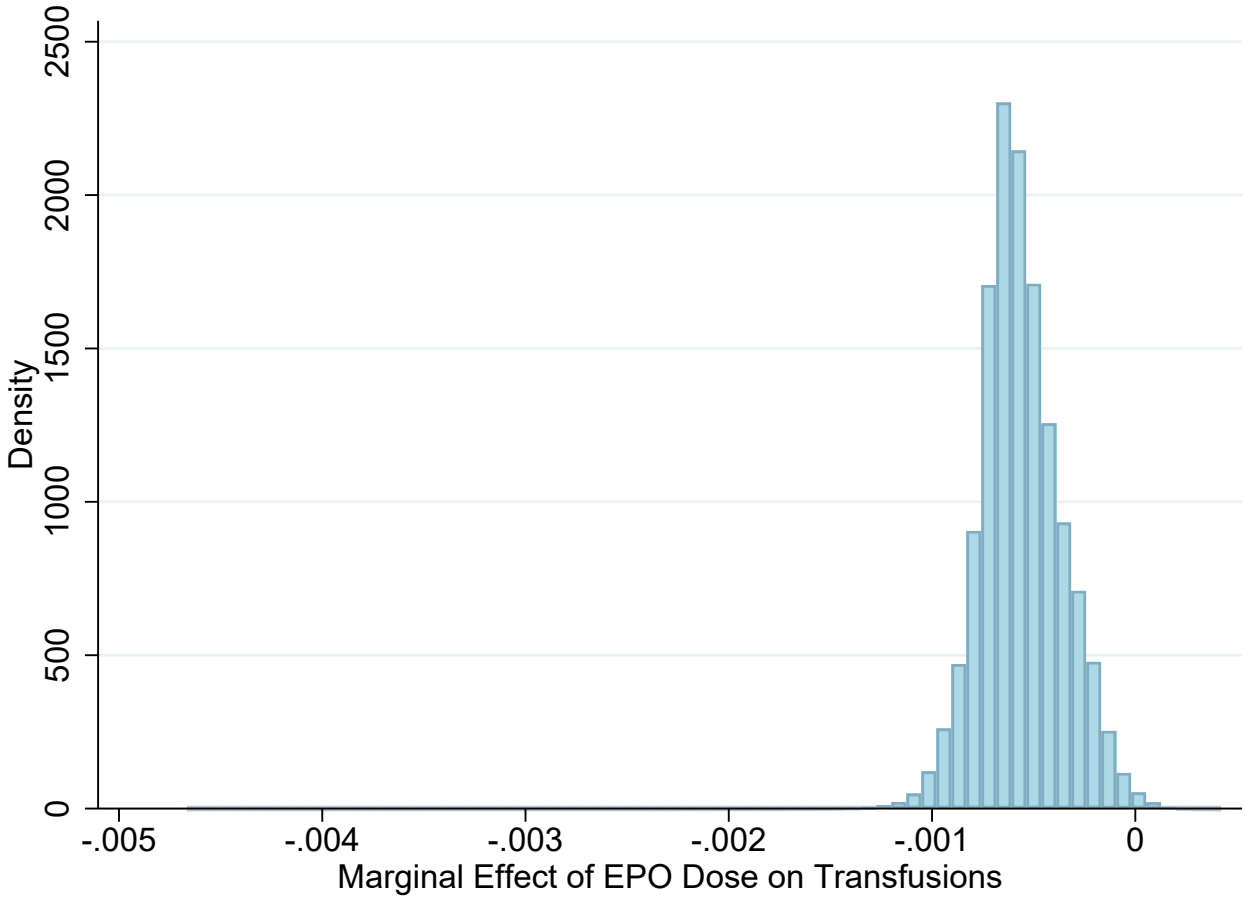
Table A8
The Effect of EPO on Hospitalizations and Mortality

	Hosp., Any Cause		Hosp., Cardiac Event		Hosp., Septicemia		Mortality	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
EPO	0.000147***	0.0000805	0.0000146***	0.000121	-0.000000784	0.0000275	-0.000112***	0.000144*
	(0.00000343)	(0.000237)	(0.00000119)	(0.0000957)	(0.000000586)	(0.0000524)	(0.000000871)	(0.0000646)
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		55.76		55.76		55.76		55.76

Notes: OLS and IV estimates from equation (3). Dependent variables are binary outcomes. EPO doses are censored at the 99th percentile and measured in 1000 IUs. An observation is a patient-month. Sample consists of observations from October 2008 to September 2012 for in-center 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 is freestanding or hospital-based, and chain ownership, 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.

Figure A3

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 in-center 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 censored at the 99th percentile and measured in 1000 IUs.

Table A9

Difference in EPO by the Responsiveness of Transfusions to EPO

	(1) EPO	(2) EPO	(3) Transfusion	(4) Transfusion	(5) Mortality	(6) Mortality
EPO-Responsiveness Z-Score	-1.407***	-1.162***	-0.00967***	-0.00968***	-0.00830***	-0.00830***
	(0.106)	(0.106)	(0.000163)	(0.000162)	(0.000105)	(0.000105)
PPS	-4.861***		0.00310***		0.0000909	
	(0.238)		(0.000282)		(0.000183)	
EPO-Responsiveness Z-Score × PPS	1.886***	1.359***	0.00372***	0.00375***	0.00443***	0.00442***
	(0.105)	(0.104)	(0.000181)	(0.000182)	(0.000108)	(0.000109)
Time Trend	-0.508***		-0.0000173		-0.000111***	
	(0.0140)		(0.0000126)		(0.00000829)	
Facility Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1
R-squared	0.119	0.122	0.00916	0.00922	0.00484	0.00485
Dep. Var. Mean	50.18	50.18	0.0279	0.0279	0.0159	0.0159
Observations	9979284	9979284	9979284	9979284	9979284	9979284

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are censored at the 99th percentile and measured in 1000 IUs. Dependent variables in columns (3)–(6) 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. EPO-Responsiveness 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 October 2008 to September 2012 for in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 A10

Difference in EPO by Responsiveness of Transfusions to EPO & Chain Status

	(1) EPO	(2) EPO	(3) Transfusion	(4) Transfusion	(5) Mortality	(6) Mortality
Chain Ownership	8.657***	9.906***	0.000381	-0.000576	0.000141	0.000306
	(1.878)	(1.868)	(0.00104)	(0.000981)	(0.000491)	(0.000442)
EPO-Responsiveness	-0.524**	-0.905***	-0.00995***	-0.0100***	-0.00790***	-0.00792***
Z-Score	(0.172)	(0.171)	(0.000339)	(0.000334)	(0.000242)	(0.000236)
EPO-Responsiveness	-1.125***	-0.331	0.000374	0.000457	-0.000527*	-0.000494+
Z-Score × Chain	(0.213)	(0.213)	(0.000386)	(0.000380)	(0.000268)	(0.000261)
PPS	-2.641***		0.00471***		-0.0000269	
	(0.567)		(0.000623)		(0.000378)	
PPS × Chain	-2.774***		-0.00204**		0.000144	
	(0.602)		(0.000667)		(0.000410)	
EPO-Responsiveness	0.788***	0.396+	0.00347***	0.00353***	0.00404***	0.00404***
Z-Score × PPS	(0.209)	(0.214)	(0.000400)	(0.000398)	(0.000231)	(0.000230)
EPO-Responsiveness	1.393***	1.209***	0.000295	0.000253	0.000502+	0.000496+
Z-Score × PPS × Chain	(0.241)	(0.245)	(0.000449)	(0.000446)	(0.000262)	(0.000261)
Time Trend	-0.274***		-0.0000392		-0.0000943***	
	(0.0248)		(0.0000248)		(0.0000159)	
Time Trend × Chain	-0.290***		0.0000307		-0.0000206	
	(0.0239)		(0.0000259)		(0.0000162)	
Facility Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1
R-squared	0.120	0.122	0.00917	0.00922	0.00485	0.00485
Dep. Var. Mean	50.18	50.18	0.0279	0.0279	0.0159	0.0159
Observations	9979284	9979284	9979284	9979284	9979284	9979284

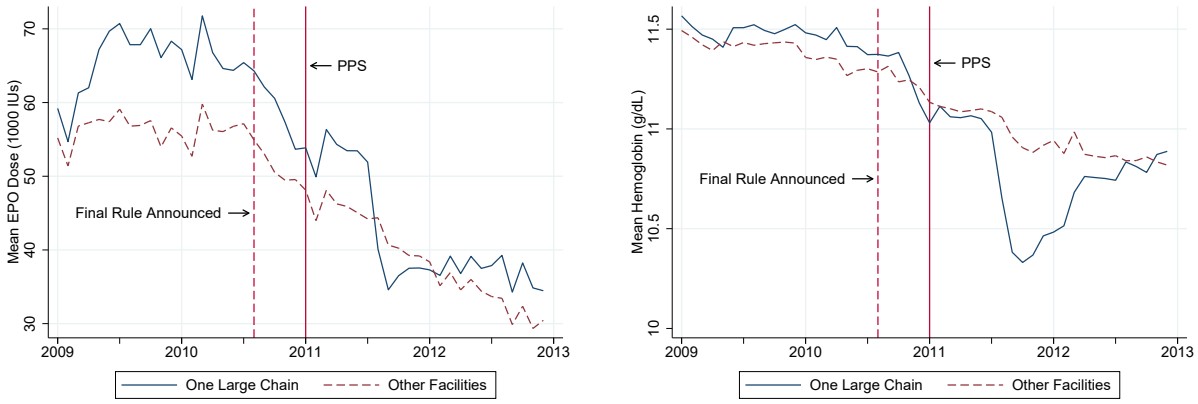
Notes: OLS estimates from equation (8) with additional interactions with an indicator for chain ownership. Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are censored at the 99th percentile and measured in 1000 IUs. Dependent variables in columns (3)–(6) are binary outcome measures. 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. EPO-Responsiveness 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 October 2008 to September 2012 for in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% level, respectively.

D. 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. Our understanding is that Fresenius now has year-to-year contracts with Amgen.

We find a distinct drop in average HGB levels in mid-2011. As discussed in Appendix A, this corresponds to the second FDA black box warning and the Medicare's removal of low HGB levels as a QIP measure. Furthermore, it also corresponds to the renegotiation of multiple large chains' contracts with Amgen, the monopoly supplier of EPO at the time. We see that the sharp drop in EPO and HGB levels in mid-2011 occurs only for patients at one of these large chains. This provides further evidence that the cause of the discrete drop in EPO and HGB after the initial response to the payment reform is likely not the FDA black box warning but rather the renegotiation of this chain's supply agreement with Amgen. Because the contract renegotiation occurred at the same time as the bundled payment reform, the renegotiation likely reflects a change in this particular chain's strategy following the bundle. If this is the case, then the drop in EPO and HGB occurring in mid-2011 would be attributable to the bundle, with the delay highlighting the sticky nature of chains' supply agreements.

Figure A4
EPO Doses and HGB 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 in-center 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 censored at the 99th percentile and measured in 1000 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 start of PPS in January 2011, while the dashed vertical line indicates the announcement of the final rule for PPS.

E. Additional Time Series Results

Table A11
Effect of Bundle on Medicare Spending

	Medicare Spending				
	(1) Inpatient	(2) Outpatient	(3) Part D	(4) Dialysis	(5) Total
PPS	-83.23***	31.38***	53.61***	68.81***	-19.78
	(11.16)	(2.211)	(1.923)	(4.234)	(15.63)
Pat/Fac Controls	1	1	1	1	1
Facility FE	1	1	1	1	1
Dep. Var. Mean	2557.5	393.7	465.2	2286.8	7555.4
R-squared	0.0133	0.0168	0.0700	0.0819	0.0309
Observations	9771287	9771287	9771287	9771287	9771287

Notes: OLS estimates from equation (1). Dependent variables are components of Medicare spending, denominated in dollars. An observation is a patient-month. PPS is an indicator variable for January 2011 or later. Sample consists of observations from January 2009 to December 2012 for in-center 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 is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 A12
Effect of Bundle on EPO and Outcomes, Pre- and Post-Trends

	(1) EPO	(2) HGB	(3) Transfusion	(4) Hosp., Any Cause	(5) Hosp., Cardiac Event	(6) Mortality
PPS	-6.829***	-0.231***	0.00481***	0.00106+	0.000141	0.0000603
	(0.277)	(0.00645)	(0.000289)	(0.000585)	(0.000249)	(0.000181)
Time Trend	-0.189***	-0.00935***	0.0000707***	-0.000211***	-0.000102***	-0.0000397***
	(0.0189)	(0.000354)	(0.0000155)	(0.0000342)	(0.0000147)	(0.0000103)
Post-PPS Trend Change	-0.688***	-0.00271***	-0.0000868***	-0.000193***	-0.0000168	-0.0000104
	(0.0214)	(0.000420)	(0.0000209)	(0.0000440)	(0.0000179)	(0.0000120)
Pat/Fac Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Dep. Var. Mean	48.50	11.12	0.0282	0.138	0.0271	0.0157
R-squared	0.138	0.0772	0.0118	0.0215	0.00791	0.00850
Observations	10077264	8181736	10077264	10077264	10077264	10077264

Notes: OLS estimates from equation (2). Dependent variable in column (1) is monthly EPO dose. EPO doses are censored at the 99th percentile and measured in 1000 IUs. Dependent variable in column (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)–(6) 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 in-center 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 is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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
Effect of Bundle on Medicare Spending, Pre- and Post-Trends

	Medicare Spending				
	(1) Inpatient	(2) Outpatient	(3) Part D	(4) Dialysis	(5) Total
PPS	19.89	-4.899*	12.07***	8.641*	-9.478
	(15.71)	(2.178)	(1.498)	(3.991)	(20.03)
Time Trend	2.399**	1.848***	1.232***	0.427+	10.62***
	(0.896)	(0.132)	(0.102)	(0.223)	(1.195)
Post-PPS Trend Change	-16.06***	0.0220	1.873***	5.553***	-23.30***
	(1.133)	(0.166)	(0.145)	(0.256)	(1.528)
Pat/Fac Controls	1	1	1	1	1
Facility FE	1	1	1	1	1
Dep. Var. Mean	2557.5	393.7	465.2	2286.8	7555.4
R-squared	0.0133	0.0168	0.0703	0.0827	0.0309
Observations	9771287	9771287	9771287	9771287	9771287

Notes: OLS estimates from equation (2). Dependent variables are components of Medicare spending, denominated in dollars. An observation is a patient-month. 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. Sample consists of observations from January 2009 to December 2012 for in-center 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 is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 the exercise from Section 5 using equation (6) to estimate heterogeneity in the effect of EPO on patients' end-of-month HGB levels. 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 construct each patient's EPO-responsiveness Z-score in a similar manner as before, the one difference here being that we do not multiply by -1, as the distribution of marginal effects of EPO on HGB is already positive, as shown in Figure A5. We classify patients for whom EPO is effective at raising HGB as "EPO-responsive."

It is natural to expect patients who respond to EPO — in the sense that it increases their HGB levels — to be the same patients for whom EPO decreases their likelihood of needing a transfusion, but this need not be the case: we find that the correlation between these two measures of EPO responsiveness is 0.2641. Appendix Table A14 provides the number of patient-month observations in the quintiles of the estimated marginal effect of EPO on HGB and transfusion rates. It generally shows that patients in the low or high end of the distribution of HGB-responsiveness are in the same end of the distribution for transfusion-responsiveness, although these patients have somewhat different observable characteristics, as shown in Table A15.

Figure A6 breaks out time trends in EPO doses 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. Looking at trends in HGB levels in Figure A6, we see an overall decrease in HGB levels, but this decrease is greater for EPO-responsive patients (those who experience the smallest drop in EPO doses).

Figure A6 also shows a pronounced drop and recovery of HGB levels for EPO-unresponsive patients. In January 2012, the reporting requirements for HGB levels changed. Prior to this date, HGB only had to be reported on claims for reimbursement of EPO, whereas all claims were required to report HGB after. This means that prior to 2012, we only observe HGB levels for those patients who also receive EPO. To reduce concerns 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 panel (b) of Figure A6 using only those observations for which the EPO dose is strictly positive, meaning that we restrict our sample to only those observations for which EPO was required to be reported both before

Table A14
Crosstabulation of EPO-Responsiveness with Respect to HGB and to Transfusion Rates

	EPO-Responsiveness of Transfusions, Quintiles					
EPO-Responsiveness of HGB	First	Second	Third	Fourth	Fifth	Total
First Quintile	499,526	494,588	421,951	339,501	259,897	2,015,463
Second Quintile	493,072	437,490	425,591	367,791	291,527	2,015,471
Third Quintile	417,081	412,018	426,548	428,714	331,082	2,015,443
Fourth Quintile	372,933	384,407	410,052	443,698	404,390	2,015,480
Fifth Quintile	232,873	286,930	331,350	435,758	728,521	2,015,432
Total	2,015,485	2,015,433	2,015,492	2,015,462	2,015,417	10,077,289

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 transfusions as the dependent variable of (6).

and after the change in reporting requirements. We find in Figure A7 that, although 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 A16 and echo the results using transfusions. Prior to the bundle, EPO-responsive patients received lower doses than unresponsive patients did, which is in line with the incentives of the pre-2011 era for providers seeking to maximize profits without violating clinical standards. As discussed in Section 2, clinical guidelines at the time directed providers to avoid treating patients with HGB levels over 12 g/dL, so EPO-unresponsive patients presented 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 HGB one standard deviation below the mean received 1496 more units of EPO than a patient with similar observable characteristics who has an 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 patients. We also see that the EPO-responsive patients had higher HGB levels than the EPO-unresponsive did prior to the bundle. After the bundle, the HGB levels of both types of patients decreased, but more so for the EPO-responsive types, suggesting a potential cost of the reallocation from low-return to higher-return patients. As shown in Table A17, this reallocation of EPO and the resulting change in HGB levels were more extreme for patients at chain-owned facilities.

Table A15

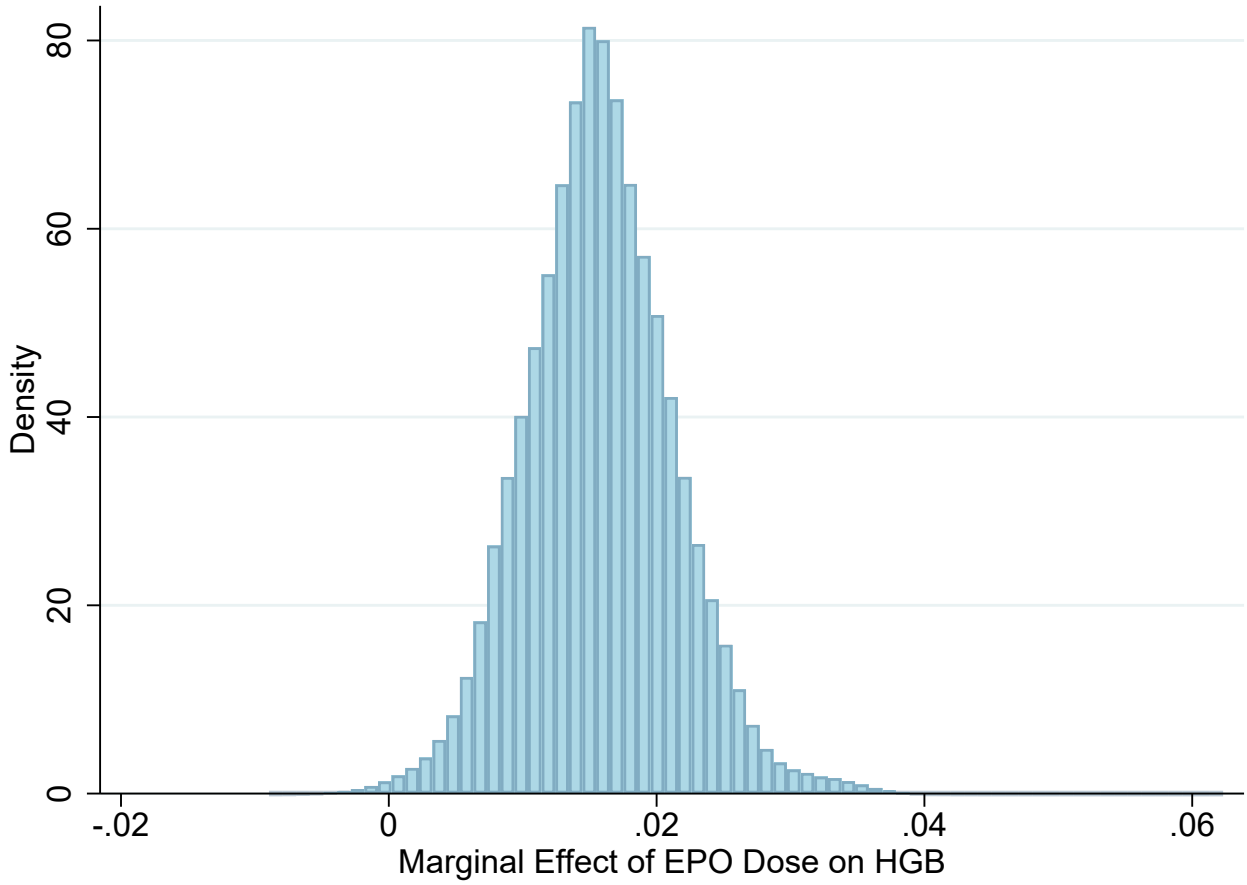
Patient Descriptive Statistics by the Responsiveness of Hemoglobin to EPO

	EPO-Responsiveness Quintile				
	First	Second	Third	Fourth	Fifth
Patient Characteristics					
Marginal Effect of EPO	0.0083	0.0129	0.0154	0.0181	0.0232
Predicted Mortality	0.013	0.014	0.015	0.018	0.021
Age (Years)	54.66	58.70	61.57	67.98	72.69
Months with ESRD	58.51	44.69	37.96	36.09	34.20
Black	0.402	0.378	0.413	0.367	0.354
Male	0.880	0.704	0.609	0.450	0.170
Diabetic	0.443	0.509	0.543	0.558	0.575
Hypertensive	0.929	0.914	0.902	0.894	0.891
Incident Hemoglobin	10.501	9.889	9.743	9.769	9.770
Facility Characteristics					
Facility Elevation (ft)	669.4	663.4	644.4	635.6	585.7
Independent Ownership	0.218	0.221	0.215	0.218	0.220
Resource Use					
EPO Dose (1000 IUs)	60.15	61.23	60.41	58.35	55.79
Receives Any EPO	0.718	0.753	0.774	0.789	0.813
Medicare Spending ($)					
Total	7,378	7,563	7,513	7,499	7,464
Inpatient	2,537	2,686	2,654	2,601	2,526
Dialysis	2,385	2,286	2,227	2,190	2,137
Part D	488	445	411	371	377
Outpatient	365	376	368	365	349
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	0.1337	0.1437	0.1461	0.1469	0.1476
Cardiac Event	0.0254	0.0273	0.0292	0.0308	0.0333
Septicemia	0.0081	0.0087	0.0088	0.0094	0.0093
Transfusions					
Total	0.0213	0.0247	0.0257	0.0268	0.0263
Inpatient	0.0169	0.0200	0.0210	0.0220	0.0221
Outpatient	0.0049	0.0053	0.0053	0.0054	0.0047
Emergency Room	0.0001	0.0001	0.0001	0.0001	0.0001
Unique Patients	48,746	49,246	50,477	53,152	54,883
Patient-Months	444,524	441,453	460,212	490,700	513,553

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 using coefficents from a regression of mortality on patient controls and time fixed effects on observations from 2009 and 2010. 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 censored at the 99th percentile and measured in 1000 IUs. Facility elevation is measured in feet above sea level. Predicted values come from IV estimates of equation (6) with hemoglobin as the dependent variable.

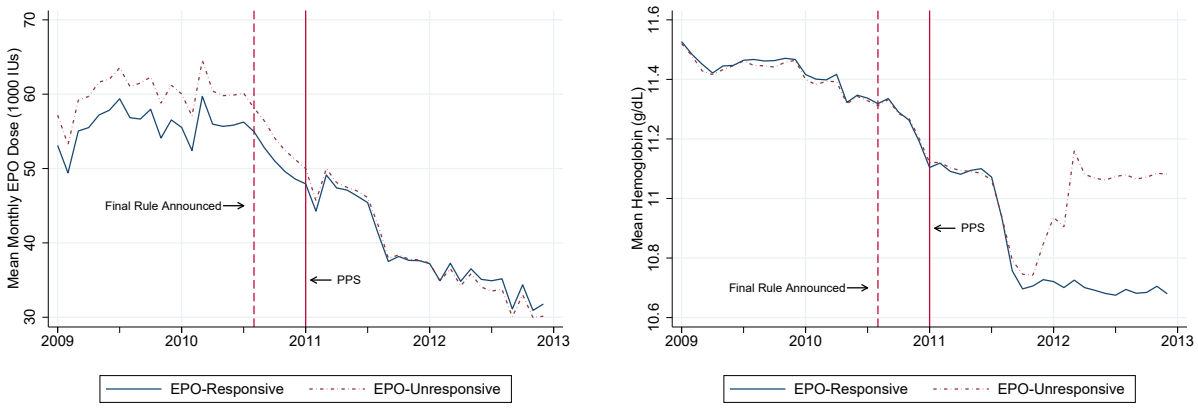
Figure A5

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



Notes: Predicted values come from IV estimates of equation (6) with hemoglobin as the dependent variable. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 censored at the 99th percentile and measured in 1000 IUs. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter.

Figure A6
EPO Dosing and HGB Levels Over Time by Responsiveness of HGB to EPO

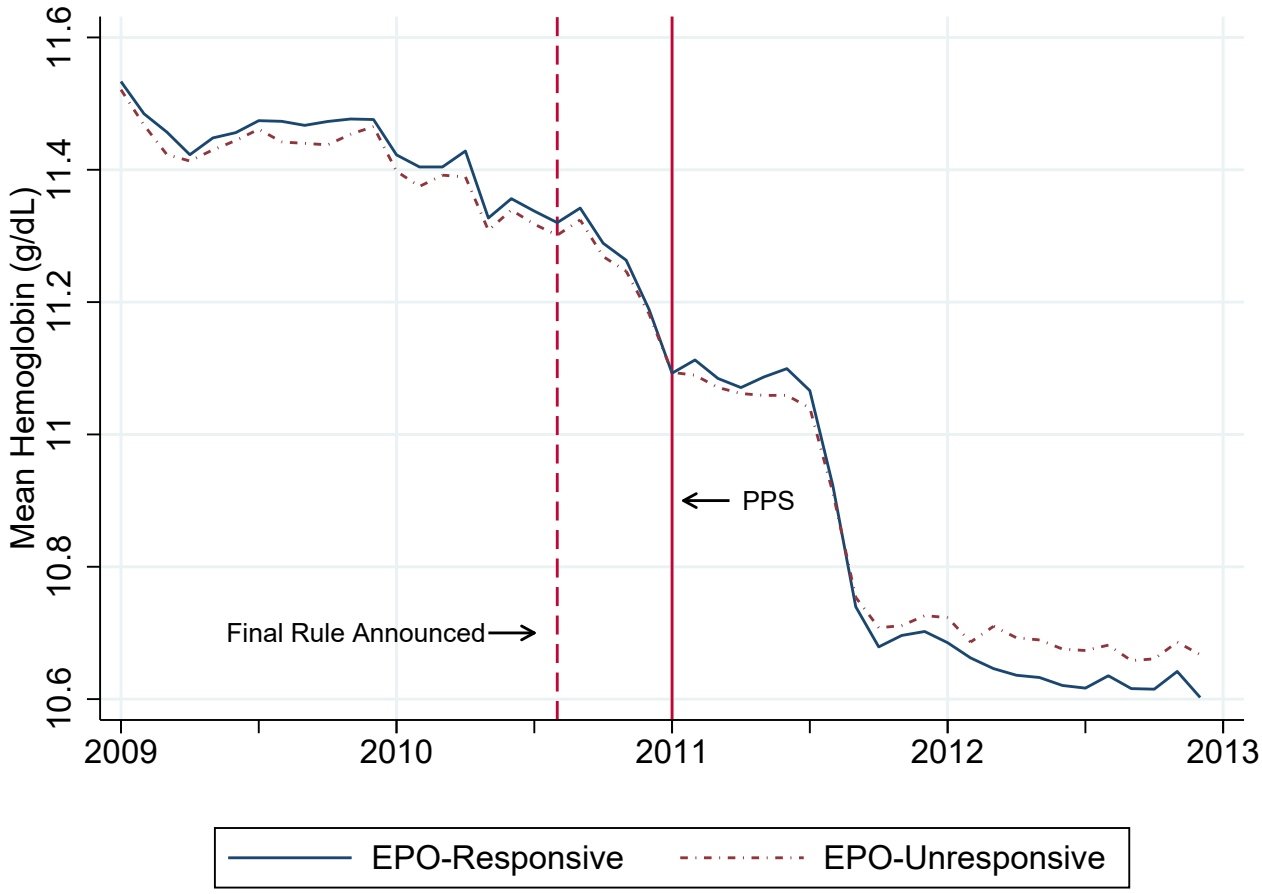


(a) Monthly EPO Dose Over Time by EPO Responsiveness

(b) 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) with hemoglobin as the dependent variable. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 censored at the 99th percentile and measured in 1000 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 start of PPS in January 2011, while the dashed vertical line indicates the announcement of the final rule for PPS.

Figure A7
HGB Levels Over Time by EPO Responsiveness (Sample Restricted to Positive EPO Dose)



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) with hemoglobin as the dependent variable. 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 in-center 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 sample included in the figure is further limited to those receiving a strictly positive EPO dose. The solid vertical line indicates the start of PPS in January 2011, while the dashed vertical line indicates the announcement of the final rule for PPS.

Table A16
Difference in EPO by the Responsiveness of HGB to EPO

	(1) EPO	(2) EPO	(3) HGB	(4) HGB	(5) Mortality	(6) Mortality
EPO-Responsiveness Z-Score	-1.496***	-1.453***	0.00378**	0.00398**	0.00164***	0.00164***
	(0.104)	(0.104)	(0.00125)	(0.00126)	(0.0000615)	(0.0000615)
PPS	-6.298***		-0.224***		0.0000509	
	(0.275)		(0.00652)		(0.000182)	
EPO-Responsiveness Z-Score × PPS	1.661***	1.555***	-0.0785***	-0.0782***	0.000238**	0.000236**
	(0.101)	(0.101)	(0.00185)	(0.00185)	(0.0000790)	(0.0000790)
Time Trend	-0.521***		-0.0110***		-0.0000389***	
	(0.0146)		(0.000329)		(0.00000801)	
Facility Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1
R-squared	0.121	0.124	0.0729	0.0763	0.00277	0.00277
Dep. Var. Mean	48.50	48.50	11.12	11.12	0.0157	0.0157
Observations	10077264	10077264	8181736	8181736	10077264	10077264

Notes: OLS estimates from (8). The dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are censored at the 99th percentile and measured in 1000 IUs. The dependent variable in columns (3)–(4) is hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. The dependent variable in columns (5)–(6) is an indicator for patient mortality. 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. EPO-Responsiveness Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of (6) with hemoglobin as the dependent variable. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 A17

Difference in EPO by the Responsiveness of HGB to EPO & Chain Status

	(1) EPO	(2) EPO	(3) HGB	(4) HGB	(5) Mortality	(6) Mortality
Chain Ownership	10.49***	11.14***	0.0171	0.000582	-0.000249	0.000105
	(1.773)	(1.777)	(0.0244)	(0.0215)	(0.000483)	(0.000436)
EPO-Responsiveness	-0.963***	-1.130***	0.00305	0.00269	0.00145***	0.00145***
Z-Score	(0.188)	(0.183)	(0.00347)	(0.00353)	(0.000134)	(0.000134)
EPO-Responsiveness	-0.671**	-0.413+	0.000938	0.00161	0.000244	0.000253+
Z-Score × Chain	(0.224)	(0.219)	(0.00369)	(0.00377)	(0.000150)	(0.000151)
PPS	-2.733***		-0.201***		-0.000362	
	(0.718)		(0.0213)		(0.000377)	
PPS × Chain	-4.416***		-0.0298		0.000513	
	(0.753)		(0.0222)		(0.000408)	
EPO-Responsiveness	0.376	0.351	-0.0607***	-0.0598***	0.000289	0.000288
Z-Score × PPS	(0.237)	(0.230)	(0.00513)	(0.00520)	(0.000181)	(0.000181)
EPO-Responsiveness	1.577***	1.494***	-0.0217***	-0.0223***	-0.0000727	-0.0000726
Z-Score × PPS × Chain	(0.263)	(0.256)	(0.00547)	(0.00554)	(0.000201)	(0.000201)
Time Trend	-0.291***		-0.0114***		-0.0000123	
	(0.0253)		(0.000835)		(0.0000153)	
Time Trend × Chain	-0.282***		0.000591		-0.0000333*	
	(0.0241)		(0.000809)		(0.0000157)	
Facility Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1
R-squared	0.123	0.124	0.0729	0.0762	0.00277	0.00277
Dep. Var. Mean	48.50	48.50	11.12	11.12	0.0157	0.0157
Observations	10077264	10077264	8181736	8181736	10077264	10077264

Notes: OLS estimates from equation (8). Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are censored at the 99th percentile and measured in 1000 IUs. Dependent variable in columns (3)–(4) is hemoglobin. Hemoglobin is winsorized from below to 5 and from above to 20 and is measured in grams per deciliter. The dependent variable in columns (5)–(6) is an indicator for patient mortality. 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. EPO-Responsiveness Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of (6) with hemoglobin as the dependent variable. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar month fixed effects. Standard errors clustered by facility are in parentheses. +, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% level, respectively.

G. Supplemental Tables and Figures from Section 5

Figure A8 provides coefficient estimates for β_1 and β_3 in equation (6). Figure A9 reports the first-stage F-statistics from our estimation of equation (6), showing that the majority are above 10, a common benchmark for an instrument not to be considered weak. Table A18 demonstrates that most of the variation in marginal effects comes from variation between patients.

Tables A19 and A20 present OLS estimates from equation (8) with various dependent variables that were not presented in Section 5. Tables A21–A23 present estimates of an equation similar to equation (8) that replaces the linear term for the Z-score of the estimated marginal effects, Z_{T_i}, with a series of indicator variables for the associated EPO-responsiveness quintile. We consider this specification less parametric than the linear version, though somewhat more cumbersome to interpret. To aid with interpretation, we plot model predictions in Figure A10. Like Figures 6 and 7 in the main text, these plots show how outcomes changed following the move to bundled payments. They are constructed using the coefficients from Tables A22–A23 for patients with low, average, and high responsiveness to EPO (i.e., the first, third, and fifth EPO-responsiveness quintiles, respectively).

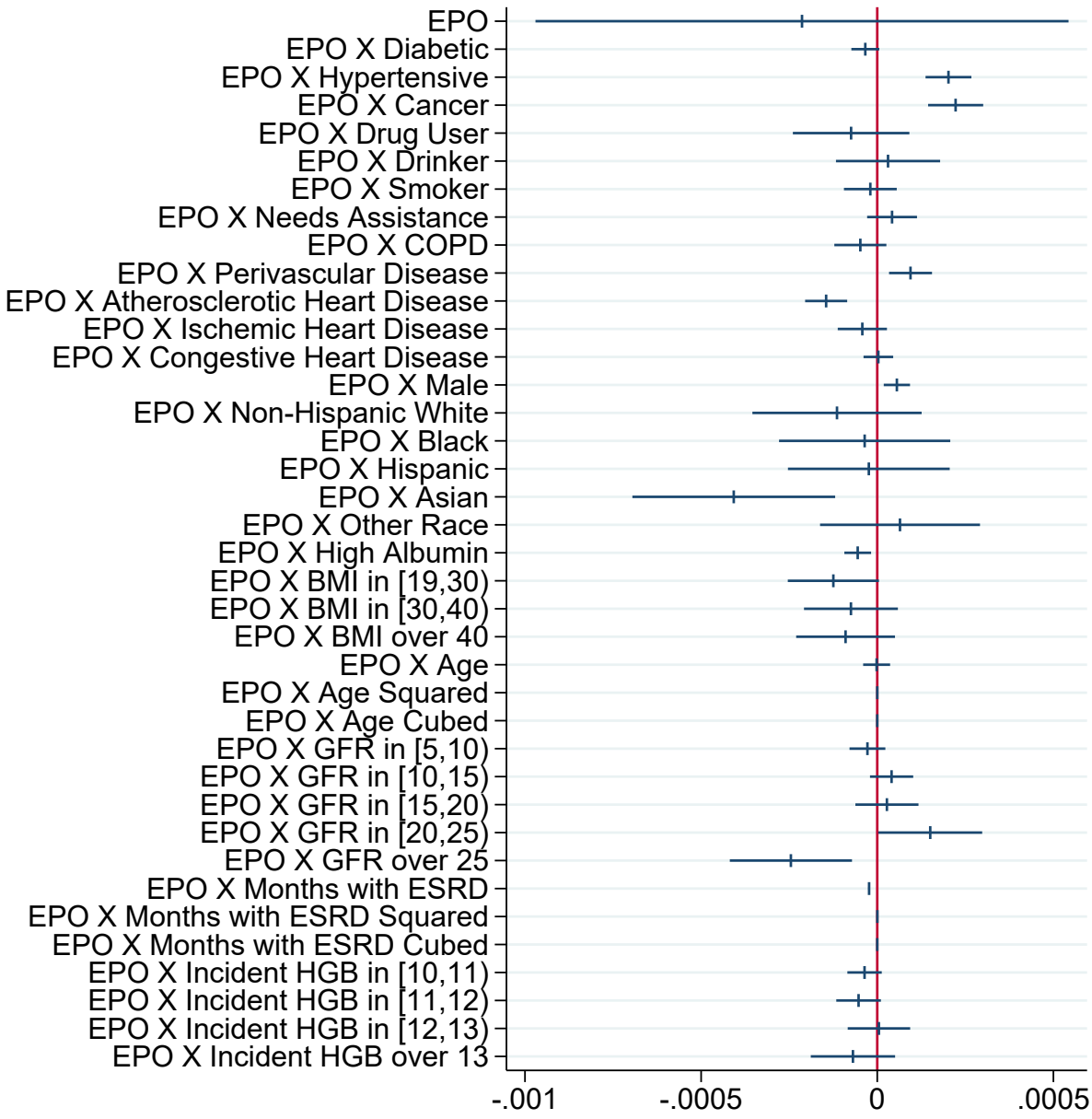
Tables A22 and A23 present estimates of equation (8) including an interaction term for chain ownership for dependent variables not reported in Table 11. These results show that despite the more aggressive reallocation of EPO in chain-owned facilities, few outcomes saw a similar reallocation, similar to the result for transfusions presented in Table 11.

Table A18
Within-Patient Marginal Effects on Transfusions

		Mean	Std. Dev.	Min	Max	N/n/T-bar
MFX of EPO on Transfusions	Overall	-0.0006	0.0002	-0.0050	0.0005	10,077,264
	Between		0.0002	-0.0042	0.0004	461,475
	Within		0.0001	-0.0021	0.0007	21.84

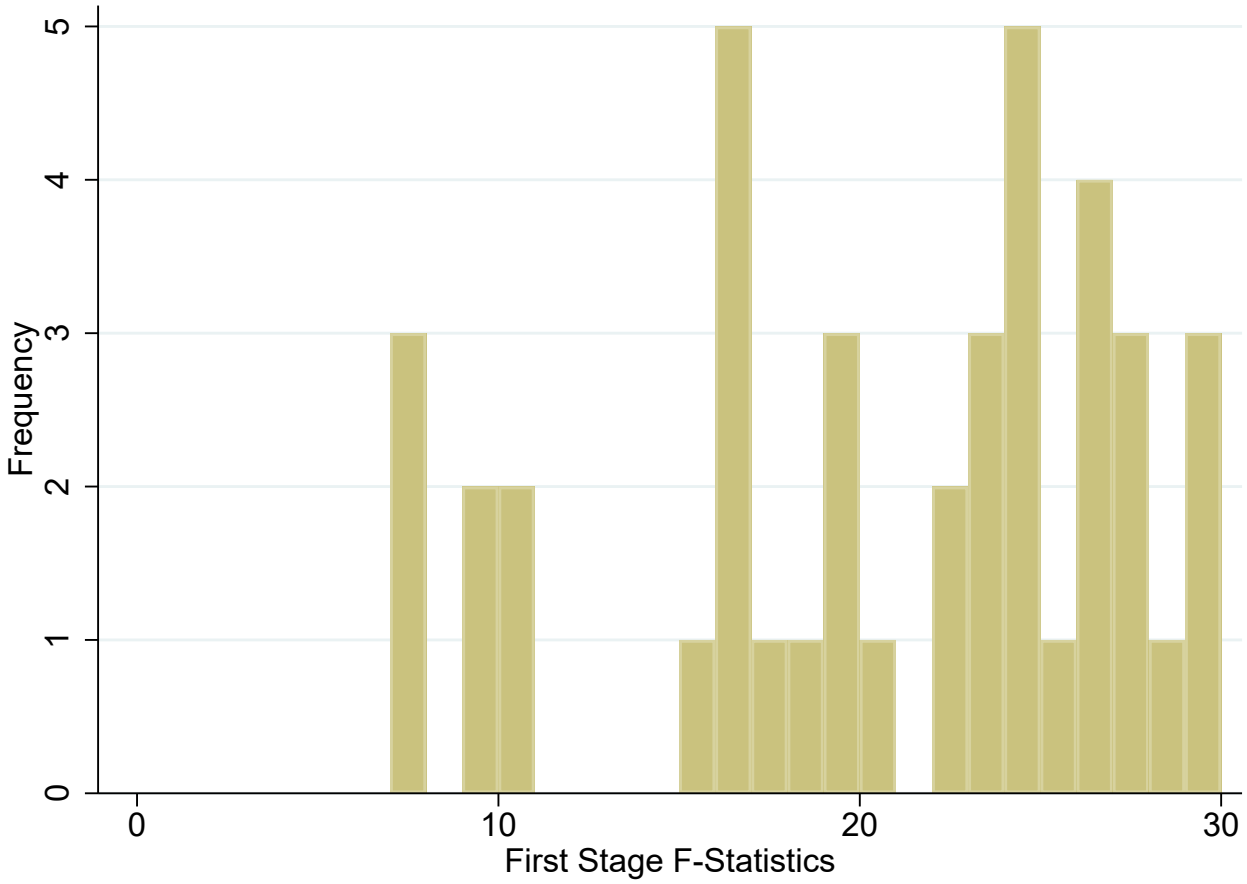
Notes: Predicted marginal effects are defined by equation (7) and come from IV estimates of equation (6). An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center hemodialysis patients between the ages of 18 and 100 with Medicare as their primary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

Figure A8
Coefficient Estimates of Heterogeneity in Responsiveness of Transfusions to EPO



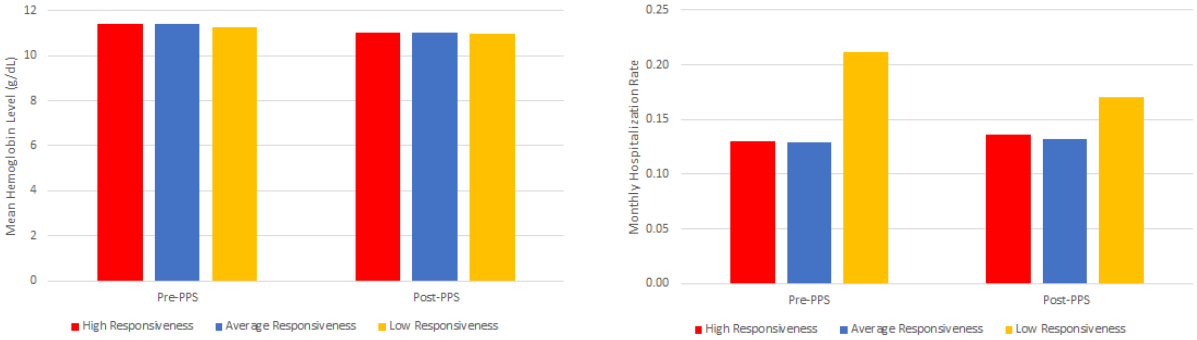
Notes: IV estimates from (6). An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and facility controls used in the 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 is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. EPO doses are censored at the 99th percentile and measured in 1000 IUs. Horizontal bands give 95% confidence intervals. Standard errors are clustered at the facility level.

Figure A9
First Stage F-Statistics



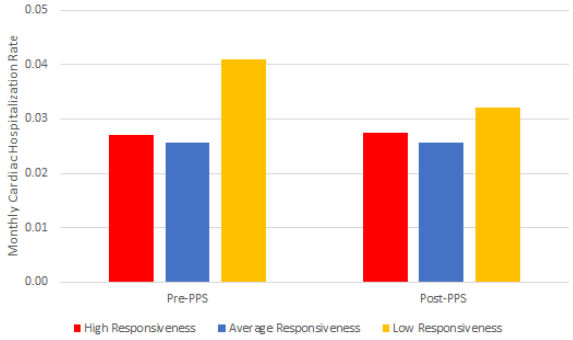
Notes: First stage F-statistics from IV estimation of (6). An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center hemodialysis patients between the ages of 18 and 100 with Medicare as their primary payer for whom we observe all patient and 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. EPO doses are censored at the 99th percentile and measured in 1000 IUs. Standard errors are clustered at the facility level.

Figure A10
Responsiveness Quintile Changes Across the Bundle: Patient Outcomes

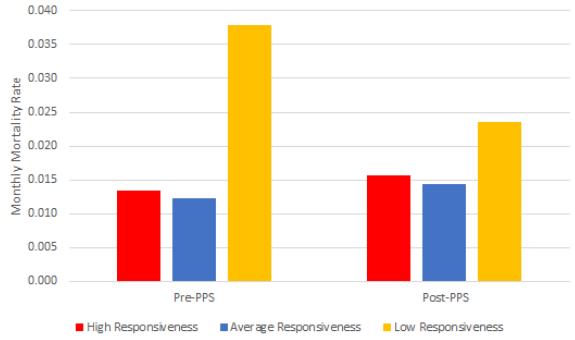


(a) Hemoglobin

(b) Hospitalization Rate



(c) Cardiac Hospitalization Rate



(d) Mortality Rate

Notes: "High Responsiveness", "Average Responsiveness", and "Low Responsiveness" refer to patients with average estimated marginal effects of EPO on transfusions in the fifth, third, and first quintiles of absolute value, respectively. High-responsiveness patients have an average estimated marginal effect at least 0.73 standard deviations above the mean, while that of low-responsiveness patients is at least 0.78 standard deviations below the mean. Marginal effects are recovered from IV estimates of equation (6) using a series of dummy variables for each responsiveness quintile, with these estimates presented in Tables A21 and A22. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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.

Table A19

Difference in Other Outcomes by Responsiveness of Transfusions to EPO

	(1) HGB	(2) HGB	(3) Any Cause Hosp.	(4) Any Cause Hosp.	(5) Cardiac Event Hosp.	(6) Cardiac Event Hosp.
EPO-Responsiveness Z-Score	0.0453***	0.0459***	-0.0264***	-0.0263***	-0.00452***	-0.00452***
	(0.00137)	(0.00137)	(0.000345)	(0.000345)	(0.000120)	(0.000120)
PPS	-0.231***		0.00108+		0.000123	
	(0.00652)		(0.000588)		(0.000249)	
EPO-Responsiveness Z-Score × PPS	-0.0181***	-0.0187***	0.0113***	0.0112***	0.00228***	0.00227***
	(0.00178)	(0.00179)	(0.000353)	(0.000354)	(0.000138)	(0.000138)
Time Trend	-0.0103***		-0.000603***		-0.000162***	
	(0.000328)		(0.0000259)		(0.0000112)	
Facility Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1
R-squared	0.0718	0.0752	0.0139	0.0139	0.00416	0.00417
Dep. Var. Mean	11.12	11.12	0.138	0.138	0.0271	0.0271
Observations	8181736	8181736	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)–(6) 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. EPO-Responsiveness 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 in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 A20

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	-638.4***	-634.4***	-40.57***	-40.50***	36.20***	34.90***	39.56***	38.98***	-940.8***	-934.6***
	(9.079)	(9.060)	(0.975)	(0.973)	(1.533)	(1.530)	(1.204)	(1.201)	(12.43)	(12.40)
PPS	25.65		-4.347*		5.307		9.271***		3.122	
	(15.78)		(2.199)		(3.959)		(1.525)		(20.22)	
EPO-Responsiveness Z-Score × PPS	345.3***	336.6***	1.395	1.179	-34.48***	-31.70***	12.59***	13.83***	437.9***	424.3***
	(9.421)	(9.443)	(1.464)	(1.474)	(1.655)	(1.652)	(1.272)	(1.274)	(12.37)	(12.41)
Time Trend	-11.85***		1.276***		3.876***		3.297***		-9.518***	
	(0.694)		(0.111)		(0.167)		(0.0826)		(0.926)	
Facility Controls	1	1	1	1	1	1	1	1	1	1
Facility FE	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
R-squared	0.00996	0.0100	0.0143	0.0144	0.0557	0.0579	0.0387	0.0389	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 variables are components of Medicare spending, denominated in dollars. An observation is a patient-month. 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. EPO-Responsiveness Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of (6). Sample consists of observations from January 2009 to December 2012 for in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 EPO by Responsiveness of Transfusion Rates to EPO, Quintiles

	(1) EPO	(2) EPO	(3) Transfusion	(4) Transfusion	(5) Mortality	(6) Mortality
Second Quintile of EPO-Responsiveness	-2.016*** (0.325)	-1.842*** (0.325)	-0.0256*** (0.000480)	-0.0255*** (0.000479)	-0.0240*** (0.000302)	-0.0240*** (0.000302)
Third Quintile of EPO-Responsiveness	-3.045*** (0.332)	-2.631*** (0.331)	-0.0290*** (0.000479)	-0.0289*** (0.000478)	-0.0255*** (0.000311)	-0.0255*** (0.000311)
Fourth Quintile of EPO-Responsiveness	-3.162*** (0.326)	-2.655*** (0.325)	-0.0299*** (0.000474)	-0.0298*** (0.000473)	-0.0251*** (0.000308)	-0.0251*** (0.000309)
Fifth Quintile of EPO-Responsiveness	-4.091*** (0.335)	-3.562*** (0.335)	-0.0299*** (0.000485)	-0.0298*** (0.000484)	-0.0245*** (0.000311)	-0.0245*** (0.000312)
PPS	-9.345*** (0.367)		-0.00772*** (0.000514)		-0.0130*** (0.000332)	
Second Quintile of EPO-Responsiveness × PPS	1.582*** (0.324)	0.987** (0.323)	0.0126*** (0.000529)	0.0125*** (0.000529)	0.0149*** (0.000327)	0.0149*** (0.000328)
Third Quintile of EPO-Responsiveness × PPS	3.620*** (0.327)	2.711*** (0.324)	0.0158*** (0.000544)	0.0157*** (0.000545)	0.0164*** (0.000330)	0.0164*** (0.000332)
Fourth Quintile of EPO-Responsiveness × PPS	4.257*** (0.323)	3.224*** (0.321)	0.0162*** (0.000533)	0.0160*** (0.000534)	0.0162*** (0.000332)	0.0162*** (0.000334)
Fifth Quintile of EPO-Responsiveness × PPS	5.633*** (0.336)	4.557*** (0.333)	0.0173*** (0.000543)	0.0171*** (0.000543)	0.0167*** (0.000336)	0.0167*** (0.000338)
Time Trend	-0.524*** (0.0146)		-0.0000867*** (0.0000123)		-0.000112*** (0.00000805)	
Facility FE	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1
R-squared	0.121	0.123	0.00946	0.00949	0.00532	0.00532
Dep. Var. Mean	48.50	48.50	0.0282	0.0282	0.0157	0.0157
Observations	10077264	10077264	10077264	10077264	10077264	10077264

Notes: OLS estimates from equation (8) using a series of dummy variables for each responsiveness quintile. "EPO-Resposiveness" refers to the standardized patient-level estimated marginal effect predicted using the IV estimates of (6). Dependent variable in columns (1)–(2) is monthly EPO dose. EPO doses are censored at the 99th percentile and measured in 1000 IUs. Dependent variables in columns (3)–(6) are binary outcome 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. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 Other Outcomes by Responsiveness of Transfusion Rates to EPO, Quintiles

	(1) HGB	(2) HGB	(3) Any Cause Hosp.	(4) Any Cause Hosp.	(5) Cardiac Event Hosp.	(6) Cardiac Event Hosp.
Second Quintile of EPO-Responsiveness	0.145***	0.146***	-0.0707***	-0.0706***	-0.0132***	-0.0132***
	(0.00401)	(0.00401)	(0.00101)	(0.00101)	(0.000384)	(0.000384)
Third Quintile of EPO-Responsiveness	0.152***	0.153***	-0.0823***	-0.0821***	-0.0153***	-0.0153***
	(0.00403)	(0.00403)	(0.00100)	(0.00100)	(0.000368)	(0.000369)
Fourth Quintile of EPO-Responsiveness	0.144***	0.145***	-0.0827***	-0.0825***	-0.0149***	-0.0149***
	(0.00403)	(0.00403)	(0.00101)	(0.00101)	(0.000381)	(0.000381)
Fifth Quintile of EPO-Responsiveness	0.144***	0.146***	-0.0811***	-0.0809***	-0.0139***	-0.0139***
	(0.00422)	(0.00423)	(0.00105)	(0.00105)	(0.000381)	(0.000381)
PPS	-0.171***		-0.0337***		-0.00686***	
	(0.00747)		(0.000985)		(0.000399)	
Second Quintile of EPO-Responsiveness × PPS	-0.0653***	-0.0656***	0.0340***	0.0338***	0.00729***	0.00727***
	(0.00475)	(0.00475)	(0.00108)	(0.00109)	(0.000431)	(0.000432)
Third Quintile of EPO-Responsiveness × PPS	-0.0753***	-0.0773***	0.0446***	0.0443***	0.00886***	0.00883***
	(0.00495)	(0.00496)	(0.00110)	(0.00110)	(0.000423)	(0.000425)
Fourth Quintile of EPO-Responsiveness × PPS	-0.0675***	-0.0701***	0.0452***	0.0449***	0.00910***	0.00907***
	(0.00498)	(0.00497)	(0.00108)	(0.00108)	(0.000438)	(0.000440)
Fifth Quintile of EPO-Responsiveness × PPS	-0.0851***	-0.0879***	0.0472***	0.0468***	0.00914***	0.00910***
	(0.00550)	(0.00551)	(0.00110)	(0.00110)	(0.000436)	(0.000437)
Time Trend	-0.0102***		-0.000632***		-0.000168***	
	(0.000328)		(0.0000259)		(0.0000112)	
Facility FE	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1
R-squared	0.0722	0.0756	0.0147	0.0147	0.00432	0.00433
Dep. Var. Mean	11.12	11.12	0.138	0.138	0.0271	0.0271
Observations	8181736	8181736	10077264	10077264	10077264	10077264

Notes: OLS estimates from equation (8) using a series of dummy variables for each responsiveness quintile. "EPO-Resposiveness" refers to the standardized patient-level estimated marginal effect predicted using the IV estimates of (6). 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)–(6) 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. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 A23
Difference in Medicare Spending by 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	-1693.6***	-1689.3***	-76.96***	-76.89***	146.5***	144.8***	78.09***	77.44***	-2388.5***	-2381.9***
of EPO-Responsiveness	(26.86)	(26.84)	(3.083)	(3.082)	(4.257)	(4.256)	(3.431)	(3.430)	(36.35)	(36.33)
Third Quintile	-1931.2***	-1921.5***	-106.0***	-105.8***	169.4***	165.9***	107.6***	106.1***	-2757.1***	-2742.3***
of EPO-Responsiveness	(26.60)	(26.58)	(3.068)	(3.067)	(4.294)	(4.295)	(3.487)	(3.482)	(36.37)	(36.33)
Fourth Quintile	-1953.1***	-1941.5***	-124.6***	-124.4***	170.3***	166.3***	115.8***	114.0***	-2814.3***	-2796.3***
of EPO-Responsiveness	(26.55)	(26.52)	(3.062)	(3.058)	(4.265)	(4.269)	(3.553)	(3.549)	(36.34)	(36.29)
Fifth Quintile	-1968.8***	-1956.7***	-125.6***	-125.4***	125.2***	121.0***	123.3***	121.4***	-2874.4***	-2855.7***
of EPO-Responsiveness	(27.67)	(27.64)	(3.087)	(3.086)	(4.346)	(4.345)	(3.520)	(3.517)	(38.20)	(38.15)
PPS	-936.5***		-9.690**		130.2***		-13.44***		-1242.5***	
	(26.83)		(3.485)		(5.047)		(2.933)		(34.73)	
Second Quintile	994.2***	979.9***	-7.584*	-7.984*	-144.7***	-139.8***	26.93***	29.04***	1255.1***	1232.4***
of EPO-Responsiveness × PPS	(28.64)	(28.64)	(3.820)	(3.821)	(4.591)	(4.591)	(3.667)	(3.674)	(37.67)	(37.68)
Third Quintile	1212.5***	1191.1***	2.594	2.123	-170.2***	-162.9***	35.15***	38.38***	1572.9***	1539.8***
of EPO-Responsiveness × PPS	(29.30)	(29.32)	(3.756)	(3.761)	(4.549)	(4.553)	(3.760)	(3.764)	(38.90)	(38.92)
Fourth Quintile	1225.1***	1201.2***	13.57***	13.05***	-164.1***	-156.0***	30.33***	33.99***	1591.9***	1554.8***
of EPO-Responsiveness × PPS	(28.72)	(28.74)	(3.766)	(3.770)	(4.532)	(4.538)	(3.890)	(3.898)	(37.81)	(37.85)
Fifth Quintile	1305.3***	1280.4***	17.30***	16.77***	-134.0***	-125.7***	21.97***	25.78***	1707.6***	1668.9***
of EPO-Responsiveness × PPS	(29.18)	(29.22)	(3.910)	(3.922)	(4.741)	(4.746)	(3.778)	(3.782)	(38.54)	(38.60)
Time Trend	-12.43***		1.171***		3.933***		3.414***		-10.32***	
	(0.695)		(0.110)		(0.167)		(0.0825)		(0.926)	
Facility FE	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
R-squared	0.0105	0.0105	0.0145	0.0146	0.0567	0.0589	0.0394	0.0397	0.0222	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) using a series of dummy variables for each responsiveness quintile. "EPO-Resposiveness" refers to the standardized patient-level estimated marginal effect predicted using the IV estimates of (6). Dependent variables are components of Medicare spending, denominated in dollars. An observation is a patient-month. 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. Sample consists of observations from January 2009 to December 2012 for in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 A24
Difference in Other Outcomes by Responsiveness of Transfusions to EPO & Chain Status

	(1) HGB	(2) HGB	(3) Any Cause Hosp.	(4) Any Cause Hosp.	(5) Cardiac Event Hosp.	(6) Cardiac Event Hosp.
Chain Ownership	0.0191	0.00193	0.00256	0.00322	0.00166*	0.00175*
	(0.0244)	(0.0214)	(0.00214)	(0.00206)	(0.000760)	(0.000706)
EPO-Responsiveness Z-Score	0.0449***	0.0446***	-0.0260***	-0.0260***	-0.00405***	-0.00411***
	(0.00349)	(0.00364)	(0.000743)	(0.000728)	(0.000241)	(0.000236)
EPO-Responsiveness Z-Score × Chain	0.000493	0.00150	-0.000535	-0.000386	-0.000611*	-0.000525+
	(0.00378)	(0.00401)	(0.000837)	(0.000817)	(0.000278)	(0.000271)
PPS	-0.207***		0.000744		0.000383	
	(0.0212)		(0.00115)		(0.000508)	
PPS × Chain	-0.0306		0.000388		-0.000341	
	(0.0221)		(0.00127)		(0.000557)	
EPO-Responsiveness Z-Score × PPS	-0.0108*	-0.0111*	0.0114***	0.0113***	0.00184***	0.00184***
	(0.00500)	(0.00492)	(0.000746)	(0.000743)	(0.000294)	(0.000292)
EPO-Responsiveness Z-Score × PPS × Chain	-0.00879+	-0.00924+	-0.000153	-0.000183	0.000573+	0.000553+
	(0.00534)	(0.00526)	(0.000848)	(0.000844)	(0.000334)	(0.000332)
Time Trend	-0.0108***		-0.000533***		-0.000138***	
	(0.000835)		(0.0000478)		(0.0000205)	
Time Trend × Chain	0.000632		-0.0000847+		-0.0000294	
	(0.000811)		(0.0000513)		(0.0000217)	
Facility Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Month FE and Trend	1	0	1	0	1	0
Year-Month FE	0	1	0	1	0	1
R-squared	0.0718	0.0752	0.0139	0.0139	0.00416	0.00417
Dep. Var. Mean	11.12	11.12	0.138	0.138	0.0271	0.0271
Observations	8181736	8181736	10077264	10077264	10077264	10077264

Notes: OLS estimates from equation (8). 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)–(6) are binary outcome 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. EPO-Responsiveness 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 in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar 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 A25

Difference in Medicare Spending by Responsiveness of Transfusions to EPO & Chain Status

	Inpatient		Outpatient		Dialysis		Part D		Total	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Chain Ownership	63.10	43.87	3.728	4.053	24.58	-13.73	36.97***	27.30**	191.6**	97.56
	(46.07)	(41.99)	(8.912)	(8.489)	(22.09)	(21.40)	(8.613)	(8.310)	(70.91)	(65.36)
EPO-Responsiveness Z-Score	-673.6***	-668.6***	-40.64***	-40.76***	42.98***	37.46***	37.26***	37.85***	-999.4***	-997.9***
	(22.12)	(21.65)	(2.122)	(2.102)	(3.240)	(3.383)	(2.660)	(2.631)	(29.69)	(28.91)
EPO-Responsiveness Z-Score × Chain	44.99+	43.78+	0.0879	0.327	-8.459*	-3.242	2.911	1.463	75.22*	81.06*
	(24.18)	(23.56)	(2.377)	(2.350)	(3.669)	(3.810)	(2.972)	(2.930)	(32.58)	(31.64)
PPS	55.08		-3.194		94.68***		18.52***		191.5***	
	(35.06)		(4.667)		(8.624)		(3.573)		(45.66)	
PPS × Chain	-35.44		-1.377		-111.2***		-10.64**		-233.3***	
	(37.79)		(5.028)		(9.485)		(3.816)		(48.95)	
EPO-Responsiveness Z-Score × PPS	333.2***	324.6***	-0.0452	-0.186	-32.03***	-27.36***	15.84***	16.81***	421.5***	411.0***
	(22.09)	(22.00)	(2.900)	(2.894)	(3.372)	(3.521)	(2.808)	(2.823)	(28.80)	(28.59)
EPO-Responsiveness Z-Score × PPS × Chain	13.06	12.93	1.769	1.671	-2.985	-5.252	-4.060	-3.761	16.89	12.97
	(24.40)	(24.26)	(3.347)	(3.340)	(3.880)	(4.002)	(3.173)	(3.188)	(31.91)	(31.64)
Time Trend	-13.08***		1.330***		2.881***		2.428***		-13.24***	
	(1.384)		(0.213)		(0.303)		(0.164)		(1.856)	
Time Trend × Chain	1.464		-0.0713		1.337***		1.043***		4.640*	
	(1.438)		(0.216)		(0.309)		(0.173)		(1.920)	
Facility Controls	1	1	1	1	1	1	1	1	1	1
Facility FE	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
R-squared	0.00996	0.0100	0.0143	0.0144	0.0559	0.0579	0.0387	0.0389	0.0216	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 variables are components of Medicare spending, denominated in dollars. An observation is a patient-month. 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. EPO-Responsiveness Z-Score is the standardized patient-level estimated marginal effect predicted using the IV estimates of (6). Sample consists of observations from January 2009 to December 2012 for in-center 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. Facility controls include facility elevation, whether the facility is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar month fixed effects. Standard errors clustered by facility are in parentheses. +, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% level, respectively.

H. The Bundle's Effect on Other Parts of Dialysis

H.1. Other Drugs

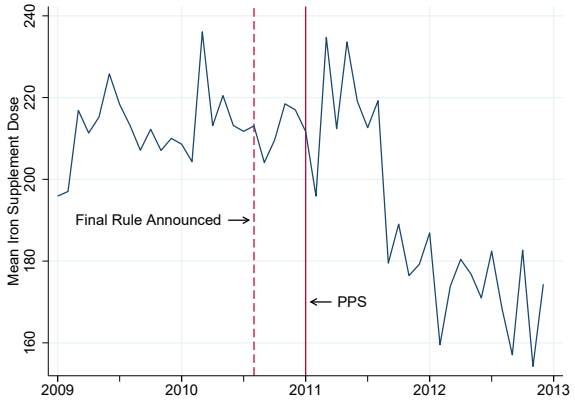
In addition to EPO, intravenous iron and vitamin D are common classes of injectable drugs administered to dialysis patients. Like EPO, these were separately billable prior to 2011, but were then bundled together with dialysis in the payment reform. Unlike EPO, these drugs were not the subject of any changes in clinical guidelines, such as the black box warning for EPO issued by the FDA in mid-2011. Figure A11 and Table A26 show that, similar to EPO, the use of these two classes of drugs declined, supporting our interpretation that financial incentives effectively reduced the quantity of injectable drugs given to dialysis patients. By contrast, we the use of Cinacalcet, a prescription drug for treating anemia that was excluded from the bundle during this period, increased substantially following the payment reform.

Table A26
Effect of Bundle on Injectable Drugs

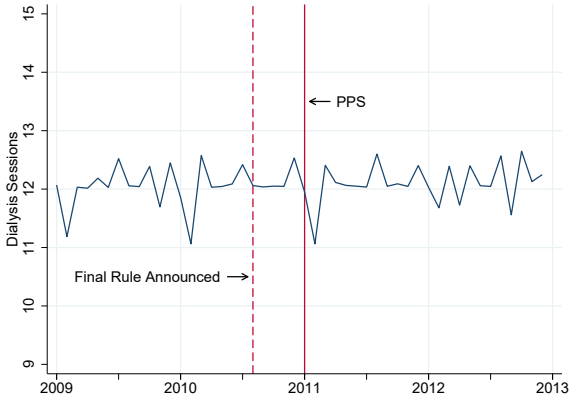
	(1) IV Iron	(2) IV Iron	(3) Vitamin D	(4) Vitamin D	(5) Cinacalcet	(6) Cinacalcet
PPS	-15.30***	4.922**	-6.219***	-3.527***	0.00701***	-0.00163**
	(1.727)	(1.650)	(0.250)	(0.210)	(0.000792)	(0.000618)
Time Trend		0.366***		-0.229***		-0.0000591
		(0.0941)		(0.0131)		(0.0000446)
Post-PPS Trend Change		-2.920***		0.191***		0.00104***
		(0.106)		(0.0134)		(0.0000558)
Pat/Fac Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Dep. Var. Mean	200.1	200.1	33.71	33.71	0.0990	0.0990
R-squared	0.0801	0.0821	0.0933	0.0936	0.0833	0.0835
Observations	10077264	10077264	10077264	10077264	10077264	10077264

Notes: OLS estimates from equations (1) and (2) in odd and even columns, respectively. Dependent variable in columns (1) and (2) is total intravenously injectable iron supplement dose in IUs. Injectible iron drugs include Ferrlecit, Venofer, Ferumoxytol, and Iron Dextran. Dependent variable in columns (3) and (4) is total injectable vitamin D supplement dose in IUs. Injectible vitamin D drugs include Calcitriol, Doxercalciferol, and Paricalcitol. Dependent variable in columns (5) and (6) is an indicator for prescription of Cinacalcet. 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 in-center 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 is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% level, respectively.

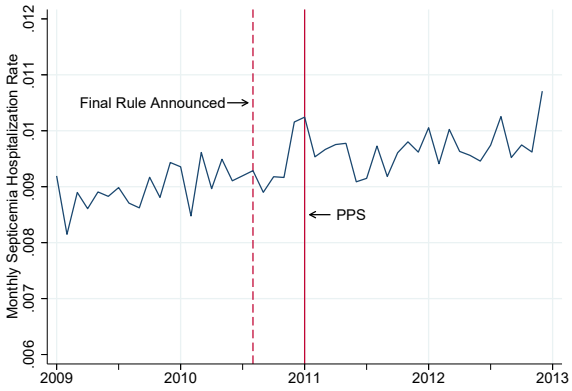
Figure A11
Use of Other Injectable Drugs



(a) Mean Monthly IV Iron Dose



(b) Mean Monthly Vitamin D Dose



(c) Share Prescribed Cinacalcet

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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. Injectible iron drugs include Ferrlecit, Venofer, Ferumoxytol, and Iron Dextran. Injectible vitamin D drugs include Calcitriol, Doxercalciferol, and Paricalcitol. The solid vertical line indicates the start of PPS in January 2011, while the dashed vertical line indicates the announcement of the final rule for PPS.

Any change in providers' use of these drugs in response to bundled payments may violate the exclusion restriction for identifying the marginal effect of EPO on health outcomes. To address this, we present an alternative approach in which we account for intravenous iron in addition to EPO, although we exclude vitamin D because it was not used to treat anemia. Table A27 presents the summary statistics with information on the use of these other injectable drugs, which are used much less often than EPO.

We re-estimate our main specification using a combined measure of intravenous iron and EPO as our

Table A27
Summary Statistics including the Use of Other Drugs

	Mean	Std. Dev.
Resource Use		
EPO Dose (1000 IUs)	48.50	64.11
Receives Any EPO	0.755	0.430
IV Iron Dose (1000 IUs)	0.20	0.26
Receives Any Iron	0.571	0.495
Vitamin D Dose (1000 IUs)	0.03	0.06
Receives Any Vitamin D	0.659	0.474
Receives Any Cinacalcet	0.099	0.299
Dialysis Sessions	12.08	9.90
Unique Patients	461,477	
Patient-Months	10,077,289	

Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 censored at the 99th percentile and measured in 1000 IUs. Injectible iron drugs include Ferrlecit, Venofer, Ferumoxytol, and Iron Dextran. Injectible vitamin D drugs include Calcitriol, Doxercalciferol, and Paricalcitol.

instrumented variable. Specifically, in each month we calculate each patient's Z-score for EPO based on the mean and standard deviation of EPO in our entire sample as well as a Z-score for intravenous iron. We sum those together for a combined total anemia drug dose Z-score, which captures each patient's position in the distribution of total anemia drug use. The results are presented in Table A28 and are very similar to our baseline results, demonstrating their robustness.

H.2. Peritoneal Dialysis

Table A29 shows a small shift from hemodialysis towards peritoneal dialysis, a change that may be due to the corresponding shift in relative profitability after the bundle that favored peritoneal dialysis (Zhang et al., 2017).

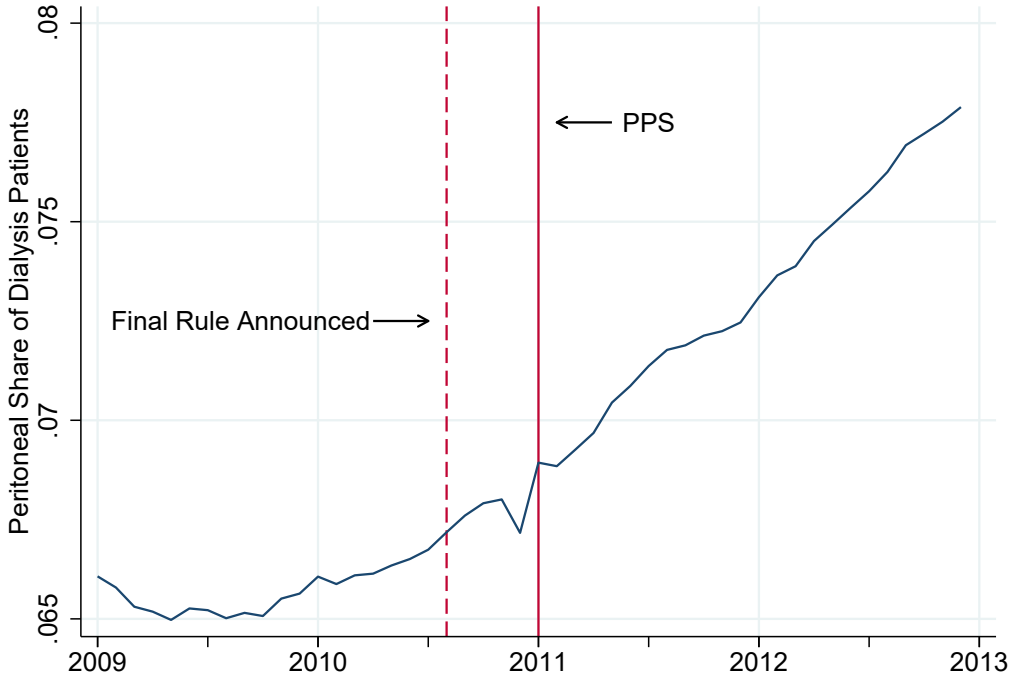
Like our results for other anemia drugs, the shift towards peritoneal dialysis may violate the exclusion restriction for identifying the marginal effect of EPO on health outcomes. In Table A30, we show that neither the share of patients receiving in-center hemodialysis nor the share receiving peritoneal dialysis changed differentially by elevation after the bundle, further supporting our identification strategy.

Table A28
Combined Injectible Anemia Drugs and Outcomes

	HGB	Transfusion	Mortality	Hosp., Any Cause	Hosp., Cardiac Event	Hosp., Septicemia
Combined Injectibles Z-score	1.584***	-0.0471***	0.0103+	0.0165	0.0148+	0.00288
	(0.384)	(0.0126)	(0.00533)	(0.0206)	(0.00795)	(0.00441)
Year-Month FE	1	1	1	1	1	1
Pat/Fac Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Dep. Var. Mean	11.12	0.0282	0.0157	0.138	0.0271	0.00939
Observations	8181736	10077264	10077264	10077264	10077264	10077264
First-Stage F-statistic	33.56	38.35	38.35	38.35	38.35	38.35

Notes: IV estimates from equation (3). 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)–(6) are binary outcomes. Combined injectibles Z-score is the mean of the patient-month's Z-scores for EPO use and IV iron use. Injectible iron drugs include Ferrlecit, Venofer, Ferumoxytol, and Iron Dextran. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 is freestanding or hospital-based, and chain ownership, 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.

Figure A12
Share of Patients on Peritoneal Dialysis



Notes: An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for ESRD 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 start of PPS in January 2011, while the dashed vertical line indicates the announcement of the final rule for PPS.

I. Differences in Timing of PPS Adoption

The PPS program allowed providers to gradually transition with the bundle comprising 25% of payments in 2011, 50% in 2012, 75% in 2013, and 100% in 2014. Alternatively, facilities could exercise

Table A29
Effect of Bundle on Dialysis Modality

	(1) Dialysis Sessions	(2) Dialysis Sessions	(3) In-Center Hemodialysis	(4) In-Center Hemodialysis	(5) Peritoneal Dialysis	(6) Peritoneal Dialysis	(7) Good URR	(8) Good URR
PPS	0.00316	-0.0224	-0.00701***	-0.00123*	0.00574***	0.000775	0.0235***	0.00701***
	(0.00829)	(0.0143)	(0.000987)	(0.000603)	(0.000860)	(0.000515)	(0.000959)	(0.000736)
Time Trend		0.000760		-0.000175**		0.000142**		-0.0000202
		(0.000790)		(0.0000602)		(0.0000508)		(0.0000511)
Post-PPS Trend Change		0.00117		-0.000253***		0.000234***		0.00182***
		(0.00129)		(0.0000658)		(0.0000573)		(0.0000686)
Pat/Fac Controls	1	1	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1	1	1
Dep. Var. Mean	12.08	12.08	0.910	0.910	0.0707	0.0707	0.933	0.933
R-squared	0.00582	0.00583	0.292	0.292	0.269	0.269	0.0911	0.0921
Observations	8869420	8869420	10355669	10355669	10355669	10355669	8560825	8560825

Notes: OLS estimates from equation (1) in odd numbered columns and (2) in even numbered columns. Dependent variable in columns (1) and (2) is monthly number of dialysis sessions. Dependent variable in columns (3) and (4) is an indicator for receiving in-center hemodialysis treatment. Dependent variable in columns (5) and (6) is an indicator for receiving peritoneal dialysis treatment. Dependent variable in columns (7) and (8) is an indicator for having a urea reduction ratio above 0.85. 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 ESRD 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 is freestanding or hospital-based, and chain ownership, as well as facility fixed effects. Further controls include calendar month fixed effects. Standard errors clustered by facility are in parentheses. $^{+}$, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% level, respectively.

a one-time option to opt in by November 2010 and immediately receive all payments under PPS in 2011. Here, we present results showing the vast majority of providers chose to immediately transition to the new PPS and our baseline results are very similar to the results if we use only the subset of immediate-adopters.

First, we attempt to determine within our data the number of facilities that chose to immediately transition to PPS by documenting whether a facility receives any positive payments for an injectable drug administered to a patient, which we view as a conservative measure of whether a facility has not fully adopted the PPS. We find that whereas more than 99.9% of facilities received payments for an injectable drug in each year prior to 2011, only 7.7% of facilities did afterwards, implying that over 92% of facilities immediately transitioned to PPS based on this measure. The number increases to the point of full adoption by 2014, with independently owned facilities comprising 83.4% of those that transitioned gradually.

Next, we compare EPO use and patient outcomes by facility according to whether the facility immediately transitioned to the PPS ("Immediate") or not ("Gradual"). Table A31 shows this comparison using data from 2010. We find that patient outcomes are quite similar across these facilities, while those that opted for a gradual transition tended to use less EPO, primarily because most of the facilities that transitioned gradually were independent, which use less EPO on average. Furthermore, we do not find large elevation differences between the facilities. These facts, along with the small number of facilities

Table A30
Differential Change by Elevation for Dialysis Modality

	(1) Dialysis Sessions	(2) In-Center Hemodialysis	(3) Peritoneal Dialysis	(4) Good URR
Facility Elevation	-0.0000138	-0.00000595	0.00000581	-0.0000117**
	(0.0000343)	(0.00000736)	(0.00000690)	(0.00000377)
Elevation × PPS	-0.00000472	-0.00000110	0.000000955	0.000000987
	(0.00000560)	(0.000000683)	(0.000000636)	(0.000000696)
Year-Month FE	1	1	1	1
Pat/Fac Controls	1	1	1	1
Facility FE	1	1	1	1
R-squared	0.00617	0.291	0.270	0.0923
Dep. Var. Mean	12.08	0.913	0.0685	0.933
Observations	8869420	7488474	7488474	8560825

Notes: OLS estimates from equation (4). Dependent variable in column (1) is monthly number of dialysis sessions, in column (2) is an indicator for receiving in-center hemodialysis treatment, in column (3) is an indicator for receiving peritoneal dialysis treatment, and in column (4) is an indicator for having a urea reduction ratio above 0.85. 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 ESRD 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 is freestanding or hospital-based, and chain ownership, 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.

that did not immediately transition, provide reassurance that selection bias does not undermine our estimates.

Nonetheless, we re-estimate our baseline results using only the sample of facilities that immediately transition to PPS. The results, shown in Table A32, demonstrate that our baseline results are robust to focusing solely on this set of facilities.

Table A31
Summary Statistics by Immediate Transition to PPS

	PPS Without Transition?		
	Opts Out	Opts In	Total
Facility Characteristics			
Facility Elevation (ft)	644.9	639.6	641.3
Independent Ownership	0.835	0.152	0.209
EPO Use			
EPO Dose (1000 IUs)	39.13	59.09	57.02
Receives Any EPO	0.550	0.796	0.769
Health Outcomes			
Hemoglobin (g/dL)	11.26	11.33	11.32
Mortality	0.017	0.016	0.016
Hospitalizations			
Any Cause	0.1484	0.1412	0.1407
Cardiac Event	0.0282	0.0282	0.0280
Septicemia	0.0113	0.0092	0.0092
Transfusions			
Total	0.0324	0.0258	0.0261
Inpatient	0.0261	0.0213	0.0215
Outpatient	0.0071	0.0051	0.0052
Emergency Room	0.0001	0.0001	0.0001
Patient-Months	167,827	2,282,122	2,485,214

Notes: An observation is a patient-month. Sample consists of observations from January to December 2010 for in-center 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 and who are treated at a facility that does not permanently close before 2011. "Gradual" facilities are those for which positive payments for injectible drugs are observed in 2011 or 2012. "Immediate" facilities are those for which no payments for injectible drugs are observed in 2011 or 2012 but which received other payments. EPO doses are censored at the 99th percentile and measured in 1000 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.

Table A32
Baseline Results Using only Facilities that Immediately Transition to PPS

	HGB	Transfusion	Mortality	Hosp., Any Cause	Hosp., Cardiac Event	Hosp., Septicemia
EPO	0.0285***	-0.000618**	0.000151*	0.000225	0.000211+	0.0000285
	(0.00823)	(0.000190)	(0.0000757)	(0.000306)	(0.000117)	(0.0000667)
Year-Month FE	1	1	1	1	1	1
Pat/Fac Controls	1	1	1	1	1	1
Facility FE	1	1	1	1	1	1
Dep. Var. Mean	11.13	0.0279	0.0157	0.138	0.0273	0.00932
Observations	7609185	9249810	9249810	9249810	9249810	9249810
First-Stage F-statistic	20.70	34.19	34.19	34.19	34.19	34.19

Notes: IV estimates from equation (3). 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 variable in column (2) is a binary variable for receiving a blood transfusion. Dependent variables in columns (3)–(6) are binary outcomes. EPO doses are censored at the 99th percentile and measured in 1000 IUs. An observation is a patient-month. Sample consists of observations from January 2009 to December 2012 for in-center 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 and who are treated at a facility that neither permanently closes before 2011 nor is observed to receive separate payment for injectible drugs in 2011 or 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 is freestanding or hospital-based, and chain ownership, 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.