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Association of a State-Wide Alternative Payment Model for Rural Hospitals With Bypass for Elective Surgeries

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ABSTRACT

Objective: This study aimed to measure the changes in rural hospital bypass for 11 common elective surgeries following the implementation of the Pennsylvania Rural Health Model (PARHM), a global budget payment model.

Study Setting and Design: We leveraged a natural experiment arising from the phase-in of PHARM in Pennsylvania. We conducted a comparative interrupted time series analysis to assess changes in rural hospital bypass, comparing trends in rural hospital bypass among patients in hospital service areas (HSAs) with PARHM-participating hospitals to patients in control HSAs with hospitals eligible for but not participating in PARHM. Analyses accounted for staggered entry into PARHM and examined outcomes up to 4 years post-entry.

Data Sources and Analytic Sample: We used Pennsylvania all-payer visit-level inpatient discharge data (2016–2022) to measure rural hospital bypass, encompassing 175,138 surgeries.

Principal Findings: The average bypass rate for elective surgeries was 59.9%, with an increasing trend observed during the study period. Overall, differential changes in bypass rates between PARHM-participating and control HSAs were not statistically significant, from a low of 0.53 percentage points (−8.17–9.22) among Cohort 2 HSAs and a high of 5.96 percentage points (−4.63–16.55) among Cohort 1 HSAs. However, among critical access hospitals, PARHM participation was associated with a significant relative increase in levels and trends in bypass rates compared to controls, from a low of 9.12 percentage points (2.45–15.79) among Cohort 1 HSAs and a high of 29.70 percentage points (12.54–46.86) among Cohort 2 HSAs. These relative increases were largely due to a stable rate in PARHM-participating HSAs and a marked decrease in control HSAs.

Conclusions: This study fills a gap in the relationship between global budgets and hospital bypass. Although PARHM did not broadly alter rural bypass rates overall, the differential increase in bypass among HSAs with CAHs participating in PARHM suggests meaningful effect heterogeneity, warranting further research and analysis of impacts on patient outcomes.

Summary

- What is known on this topic
  - Most rural-dwelling patients (> 50%) receiving elective surgery bypass their local hospital.
  - Rural hospital bypass for elective surgeries is linked to multiple factors, including hospital size, location, service availability, and perceptions of quality—and may also be influenced by hospital financial incentives.
  - Under global budget payments, which decouples revenue from volume, incentives to provide care locally—and consequently rural hospital bypass—may differ.
- What this study adds
  - We examined hospital bypass changes for 11 elective surgeries in hospital service areas (HSAs) with Pennsylvania Rural Health Model (PARHM)-participating versus non-participating PARHM-eligible hospitals using a comparative interrupted time series.
  - Between 2016 and 2022, bypass rates for elective surgeries increased in rural Pennsylvania.
  - PARHM was not associated with differential changes in bypass rates overall but was associated with a relative increase in bypass rates among patients living in HSAs with critical access hospitals.

1 | Introduction

Rural residents frequently bypass their local hospitals to seek care at other facilities, often in urban areas, even for common elective procedures [1]. This phenomenon, known as rural hospital bypass, can have significant implications for the financial sustainability of rural hospitals [2, 3] The reasons for rural hospital bypass are multifaceted and often relate to limited services, lack of specialty care, and perceptions of the local hospital quality [3–5]. Rural hospital bypass exacerbates existing financial strain on rural hospitals, as residents forgoing local care divert critical potential revenue streams [6]. This, in turn, can lead to service reductions, facility closures, and further erosion of access to care in rural areas [7]. Rural hospital bypass is common for both low-risk and high-risk elective procedures, suggesting that factors beyond clinical complexity play a role in patient decision-making [7, 8].

Rural hospital bypass is particularly salient when it comes to surgery [9]. Elective procedures, especially surgical procedures, are among the most profitable hospital services [10, 11]. Because most hospitals are paid on a fee-for-service basis, lower elective surgical volume can adversely affect a hospital's finances [12, 13]. Policymakers and health system leaders have explored approaches to address both the causes and consequences of rural hospital bypass, including enhancing the capabilities of rural hospitals, implementing alternative payment models, engaging with rural communities to better align care delivery with their needs, and leveraging telehealth and other care modalities to extend their reach [14]. While policymakers are often focused on reducing rural hospital bypass, there is discussion as to whether reducing bypass itself will preserve hospitals' financial viability and sustain access to care in rural communities [15].

Alternative payment models that decouple revenue from volume may allow hospitals to reorganize and centralize some services, enabling those hospitals to devote scarce resources to community-oriented needs. One such alternative payment model is the Pennsylvania Rural Health Model (PARHM) [16]. Launched in 2019 through a partnership between the Centers for Medicare & Medicaid Innovation and the Commonwealth of Pennsylvania, PARHM seeks to test whether global budgets coupled with care delivery transformation plans can help sustain access to care and improve health outcomes in rural communities [16–18]. Eighteen hospitals joined PARHM in cohorts across multiple years: 5 in 2019, 8 in 2020, and 5 in 2021, creating a natural policy experiment [16]. The global budget provides hospitals with a fixed amount of money, set in advance for the entire year, regardless of the volume of services they provide [16]. In addition, participating hospitals were required to develop and implement transformation plans to redesign care delivery to better meet local populations' needs [16].

One of the key features of global budgets is to decouple volume from revenue. Under traditional fee-for-service, surgical services tend to be the largest line item for hospital revenue, expenses, and profitability, so hospitals could profit more by doing more [19]. However, because revenue is fixed under PARHM's global budget, the value for surgical services changes. Hospitals have a larger financial incentive under PARHM to reduce expenditures because they retain any remaining funds at the end of the year [16–18]. PARHM placed hospital facility revenues under a global budget, but it did not change payments to physicians, who continued to have volume-based incentives.

Furthermore, there were slight differences in the global budget methodology in PARHM for critical access hospitals (CAHs) versus prospective payment system (PPS). CAH is a designation given to small rural hospitals (< 25 inpatient beds) in the United States that receive cost-based reimbursement from Medicare, whereas PPS hospitals receive payment rates that are prospectively set according to the type and severity of an admission. Under PARHM, global budgets for CAHs were reconciled to cost-based reimbursement, while global budgets for PPS hospitals were adjusted based on several factors such as unplanned volume shifts, payer mix shifts, and planned changes to service lines, among others [16–18].

Several incentives and mechanisms could either drive increases or decreases in hospital bypass under a global budget payment model. For example, because the costs of maintaining surgical departments and operating room capacity are high, hospitals in PARHM might elect to downsize capacity and increase referrals to outside hospitals for elective surgeries [20, 21]. Alternatively, under the care transformation plans tied to PARHM, hospitals could have prioritized investments in certain surgical services deemed to meet community needs, which could reduce rural hospital bypass. The theoretical ambiguity surrounding these possible effects underscores the importance of empirically examining the association between PARHM and rural hospital bypass. However, there is no previous research on the impact of hospital global budgets on rural hospital bypass.

This study seeks to evaluate the association between PARHM and rural hospital bypass for common elective surgeries in rural hospitals, with a specific focus on CAHs. Our results inform a broader understanding of the impact of global budgets and the implementation of other alternative payment models that use global budgets, such as the upcoming States Advancing All-Payer Health Equity Approaches and Development Model, which will also use global hospital budgets, and New York's Medicaid Hospital Global Budget Initiative [22, 23].

2 | Methods

2.1 | Data Sources

The University of Pittsburgh Institutional Review Board approved this study. Our primary data were visit-level inpatient discharges from the Pennsylvania Health Care Cost Containment Council (PHC4) from January 2016 through December 2022. All licensed health care facilities in Pennsylvania must report administrative data to PHC4 quarterly, which are verified by the reporting facility. These data include patient ZIP code, Inpatient Coding and International Classification of Diseases codes, admission type and source, diagnosis and procedure codes, payer, and facility. Hospital characteristics were obtained from PHC4 Facility datasets, and hospital financial data were obtained from PHC4 Financial Analysis Reports [24].

We augmented PHC4 data with data from the Dartmouth Atlas of Health Care, the American Community Survey, and HealthData.gov. The Dartmouth Atlas provided information on hospital service areas (HSAs), which delineate local health care markets for hospital services, defined by aggregating ZIP codes whose residents predominantly receive hospital care from facilities within that area [25]. The American Community Survey provided area-level measures of socioeconomic status, including education, household income, and poverty, measured at the ZIP Code Tabulation Area level. We used ACS 5-year estimates from 2016 to 2021 to obtain area-level demographic and socioeconomic measures, which we linked to PHC4 data at the HSA-level [26]. HealthData.gov provided data on COVID-19 hospitalization based on data compiled by the Department of Health and Human Services from state/territorial health departments.

2.2 | Population

Hospitals in Pennsylvania were eligible for PARHM if they were in a county defined as rural by the Center for Rural Pennsylvania (i.e., population density < 284 persons per square mile) [16]. Participation in PARM was voluntary. Among the 65 PARHM-eligible hospitals across 63 HSAs, 18 hospitals in 18 HSAs participated; this included 5 in 2019, 8 in 2020, and 5 in 2021. Among the remaining 47 non-participating PARHM-eligible (i.e., control) hospitals across 45 HSAs, 5 hospitals in 5 HSAs stopped providing inpatient services due to hospital closures, conversions, or mergers during the study period. We excluded patients residing in these HSAs, since by default they had a 100% bypass rate. The final study population consisted of 175,138 elective surgery visits from patients residing in one of the 18 PARHM-participating or 40 control HSAs between 2016 and 2022 (see Figure S1 for flow chart).

We focused on 11 common elective surgeries identified in prior research as archetypal elective surgeries frequently performed at United States rural hospitals, spanning varying levels of risk of substantial intraoperative blood loss and postoperative complications: low-risk (i.e., incisional hernia repair, percutaneous transluminal coronary angioplasty); intermediate-risk (i.e., laparoscopic cholecystectomy, laparoscopic sleeve gastrectomy, hysterectomy, spinal fusion); high-risk (i.e., total hip replacement, colectomy, total knee replacement); and very high-risk (i.e., carotid endarterectomy, coronary artery bypass graft [CABG] or aortic and mitral valve replacement [AVR + MVR]) (see Table S1 for ICD-10-PCS codes used) [7]. Past work demonstrates bypass rates of 64.1% for low-risk, 64.1% for intermediate-risk, 64.2% for high-risk, and 69.9% for very high-risk surgeries [7].

2.3 | Outcome Variables

The primary outcome was a binary variable indicating whether a patient received surgery at a hospital other than their local one. We identified rural hospital bypass at the patient level by comparing patients' HSAs of residence to the HSAs of the hospital from which the patients received their care. We considered the local hospital to be the one in the patient's HSA since this represents the primary catchment area of a hospital. Because HSAs are based on a range of factors reflecting utilization, not solely distance to the hospital, it may be a better marker than proximity alone.

We also used a more traditional definition of bypass based on driving distance in a sensitivity analysis. Patient bypass was constructed as a binary variable representing whether an eligible patient received their surgery at the nearest hospital by driving distance. Patient drive distance/time was calculated using the Bing Maps Application Programming Interface (API) and R programming language (version 4.2.3) [27]. Data on patient ZIP codes and hospital addresses were obtained from the PHC4 database. The latest shape file from the 2020 US Census data was used to calculate the geometric centroid of each ZIP Code Tabulation Area (ZCTA). The geocoded coordinates for each combination of patient and hospital were input into the Bing Maps API to calculate the driving distance/time between these locations, assuming travel on a workday at 9 AM local time. The shortest driving distance to a hospital for each ZCTA was determined by comparing the distance among all ZCTA-hospital pairs.

2.4 | Covariates

To account for differences in patient and hospital characteristics, we defined several covariates. From PHC4, we used patient age, sex, and race. We also used ICD-10 diagnostic codes to calculate the Elixhauser Comorbidity index to control for differences in patient demographics between treated and control HSAs [28]. From the ACS, we included median household income and the percent of residents who were married, uninsured, high school graduates, unemployed, and with incomes below poverty. We also used ACS data to calculate the Area Deprivation Index (ADI) and Community Assets and Relative Rurality (CARR) index. ADI was included as a measure of socioeconomic disadvantage, with higher values representing greater levels of socioeconomic deprivation [29]. CARR was used as a continuous measure of rurality that accounts for community services and infrastructure, with higher values indicating greater remoteness and less availability of services [30].

From the Health Resources and Services Administration, we included the following hospital characteristics: participation in the 340B program (which entitles hospitals to purchase drugs at discounted rates), hospital reimbursement methodology (i.e., CAHs which use cost-based reimbursement, or PPS hospitals, which use a predetermined reimbursement per admission based on diagnosis-related groups for inpatient services) [31, 32]. From PHC4, we included: hospital total margin, uncompensated care share of net patient revenue (NPR), Medicare share of NPR, Medical Assistance share of NPR, and discharges. We selected these variables because they differed between hospitals that did vs. did not join PARHM and may be related to trends in hospital volume and revenue.

2.5 | Statistical Analyses

To evaluate the impact of PARHM on hospital bypass, we implemented a surgery-level comparative interrupted time series (CITS). The CITS approach builds on the traditional interrupted time series approach by incorporating a comparison group that did not receive the intervention, allowing us to control for time-varying confounders and trends unrelated to the intervention [33]. The CITS approach does not rely on the assumption of parallel trends and therefore is more appropriate than a difference-in-differences model when pre-treatment trends differ [34]. Instead, CITS assumes that pre-intervention trends in bypass would have persisted in the absence of PARHM, and tests if outcomes in the treatment group (i.e., patients from HSAs with PARHM-participating hospitals) deviated from a pre-intervention trend by a greater amount than in the control group (i.e., patients from HSAs with non-participating PARHM-eligible hospitals). To account for the staggered entry of hospitals into PARHM, we analyzed elective surgeries among patients from each PARHM cohort compared to control HSAs (i.e., non-participating PARHM-eligible rural hospitals) separately. We consider the pre-intervention period to be between January 1, 2016 and December 31st of the year before PARHM entry (i.e., 2018 for Cohort 1, 2019 for Cohort 2, and 2021 for Cohort 3). To account for the staggered entry of hospitals into PARHM, we analyze surgical cases in each cohort of entrants (i.e., HSAs with PARHM-participating hospitals) and controls (HSAs with PARHM-eligible, but non-participating hospitals) as a sub-experiment or "stack" and we aggregate across the stack-specific treatment effects [35]. The CITS model equation is as follows:

$$Y_{ijts} = \alpha + \sum_{k=-5}^{-2} \beta_k D_{jt}^k + \sum_{k=0}^{3} \gamma_k D_{jt}^k + \delta X_{ijt} + \mu_{js} + \tau_{ts} + \varepsilon_{ijts} \quad (1)$$

In Equation (1), Y_{ijts} represents whether a patient bypassed their local hospital for the outcome of interest (e.g., any elective surgery), which is measured for surgery i in HSA j in year t in stack s; α is the intercept; D_{jt}^k indicates that hospitals in HSA j were k periods away from treatment in year t, where the first year of treatment is indexed to $k = 0$; δ is the vector of coefficients for the control variables; X_{ijt} is a vector of time-varying patient- and hospital-level characteristics; μ_{js} represents HSA-by-stack fixed effects to control for constant differences within HSAs within stacks (e.g., differences in hospital size); τ_{ts} are year-by-stack fixed effects that account for any year-related effects within stacks; and ε_{ijts} represents the error term. Standard errors were clustered by HSA to account for arbitrary serial correlation [36].

We are primarily interested in γ_k, which represents the differential (i.e., level) change in hospital bypass attributable to PARHM over time. The parameters β_k represent differences between HSAs that did and did not enter PARHM before they entered PARHM. If $\beta_k = 0$ for all values of k (i.e., from −5 to −2), it indicates that parallel trends existed between treatment and comparison HSAs prior to joining PARHM, which supports the parallel trends assumption.

We estimated weighted models using a composite of population weights and propensity score weights to estimate the average treatment effect on the treated (ATT)—that is, a treatment effect among patients residing in HSAs with PARHM-participating hospitals. Propensity score weighting was used to reduce the effects of observed confounding to more accurately estimate the effects of PARHM [37]. To generate propensity score weights, we ran a logistic regression predicting PARHM participation as a function of HSA-level demographics and hospital characteristics. We tested for multicollinearity and removed covariates with a variance inflation factor greater than five to address potential multicollinearity [38]. This process was repeated until all included covariates had a variance inflation factor no greater than five. Based on the included variables (Table 1), we calculated propensity scores in the pre-PARHM period (2016–2018) and carried them forward through the post-PARHM period.

2.6 | Robustness Checks

To test the robustness of our findings, we performed multiple sensitivity analyses: (1) defining hospital bypass based on the driving distance to the nearest hospital as described above; (2) removing 2020–2021 data to account for changes due to the COVID-19 pandemic, including a state-wide moratorium on elective surgeries [39]; (3) including patients from HSAs whose hospitals stopped providing inpatient services during the study period; (4) estimating unadjusted models by removing ATT propensity score weighting and covariates (other than fixed effects for HSAs and years); (5) restricting the sample to patients from HSAs that meet a stricter definition of rural as used by the Federal Office of Rural Health Policy (FORHP) [40]; and (6) restricting the sample to patients from HSAs with a system affiliated hospital at baseline due to the potential for increased referral of care to other hospitals.

Subgroup analyses were conducted to examine potential heterogeneity in treatment effects and include (1) stratifying the analysis by hospital type, between patients from HSAs with CAHs vs. PPS hospitals, to account for differences in global budget methodology [16, 17] and (2) stratifying the analysis by patients with

TABLE 1 | Comparison of patient demographics and hospital characteristics at baseline (2016–2018).

	PARHM HSAs $N=18$	Control HSAs $N=40$	p
Patient demographics			
Female, %	55.72%	55.91%	0.62
Age, years	63.40	63.79	<0.01*
Race: white, %	95.51%	95.41%	0.57
Ethnicity: hispanic/latino, %	0.19%	0.58%	<0.01*
Elixhauser index	2.24	2.32	<0.01*
HSA demographics			
Total population, thousands	32.14	52.88	<0.01*
Median income, $ in thousands	61.13	60.72	0.70
High school graduate, %	89.79%	88.06%	0.10
Unemployed, %	6.43%	6.04%	0.15
Uninsured, %	12.80%	13.24%	0.55
Below poverty level, %	10.90%	11.27%	0.36
Married, %	53.86%	54.00%	0.84
ADI[a]	0.59	0.53	0.29
CARR[a]	0.59	0.43	0.21
FORHP rural, *n* (%)	14 (77.78%)	18 (45.00%)	<0.01*
Hospital characteristics			
Critical access hospital, *n* (%)	5 (27.78%)	10 (25.00%)	0.70
Independent hospital[b], *n* (%)	12 (66.67%)	7 (17.50%)	<0.01*
340B participant, *n* (%)	9 (50.00%)	13 (32.50%)	0.02*
Inpatient discharges, *n*	3086.67	5581.06	0.01*
Inpatient discharge rate, (per 100 k)	1975.52	2664.94	0.11
Outpatient discharge rate, (per 100 k)	4461.54	7122.89	0.13
Total margin[c], %	−1.60%	4.26%	<0.01*
Uncompensated care share of NPR[d], %	2.67%	2.43%	0.22
Medicare share of NPR[e], %	45.57%	41.87%	0.01*
Medicaid share of NPR[f], %	13.22%	11.28%	0.04*

Note: Values are from years 2016–2018 (baseline before PARHM began). Data on patient demographics (only among those with any elective surgery) and hospital characteristics were obtained from the Pennsylvania Health Care Cost Containment Council. Data on HSA demographics was obtained from the American Community Survey.
Abbreviations: ADI, area deprivation index; CARR, community assets and relative rurality index; FORHP, federal office of rural health policy; NPR, net patient revenue.
*Significant at the $p<0.05$ level, two-sample *t*-test.
[a] *z*-scored.
[b] Independent (i.e., not merged or affiliated with another hospital or system).
[c] The ratio of total income to total revenue.
[d] Percent of uncompensated care (charity care and bad debt) relative to net patient revenue.
[e] Percent of Medicare revenue relative to net patient revenue.
[f] Percent of Medicaid revenue relative to net patient revenue.

the most common payer types: Medicare, Medicaid, or commercial insurance.

3 | Results

3.1 | Descriptive Statistics

Among the 191,671 elective surgeries on patients residing in PARHM-eligible HSAs, we had complete data for 191,600 surgeries. After excluding patients from HSAs whose hospital stopped providing inpatient services during the study period, we were left with 175,138 surgeries from residents across 18 HSAs with PARHM-participating hospitals and 40 HSAs with non-participating PARHM-eligible hospitals (Figure S1).

Table 1 summarizes characteristics of PARHM and control HSAs during the baseline period for variables used for propensity score weighting. While there were some statistically significant differences in characteristics between groups, differences in absolute values were often small. There were no clinically meaningful differences in patient demographics between groups. HSA characteristics were also generally similar, apart from PARHM hospitals being in areas with smaller populations and relatively more rural. PARHM hospitals were more likely to be independent (i.e., not part of a system), participate in the 340B Drug Program, have negative total margins, have a relatively higher Medicare and Medicaid share of net patient revenue, and have lower inpatient discharge rates compared to control hospitals.

Table S2 shows the total number of surgeries and rates of hospital bypass during the study between patients in HSAs with PARHM and control hospitals. Overall, rates of hospital bypass for any of the 11 elective surgeries was 59.79%. Rates of bypass was lowest for percutaneous transluminal coronary angioplasty (44.89%–53.53%) and highest for coronary artery bypass graft or aortic and mitral valve replacement (74.23% and 83.42%, respectively) between control and PARHM HSAs. Rates of hospital bypass were higher among very high-risk compared to low-risk elective surgeries, among commercially insured patients compared to those on Medicare or Medicaid, and among patients from HSAs with CAHs compared to PPS hospitals.

3.2 | Primary Outcome

Overall, bypass was increasing over time in both the PARHM and control hospitals both before and after PARHM began, although trends were increasing faster among patients in HSAs with a PARHM-participating hospital (Figure 1). Notable differences in bypass were observed between cohorts. Cohort 1 hospitals exhibited a reversal in trends, from decreasing bypass before the intervention to increasing bypass after PARHM's implementation. Cohort 2 hospitals exhibited increasing bypass over time, reflecting a continuation of pre-intervention trend. Cohort 3 hospitals exhibited a reversal in trends, from increasing hospital bypass before the intervention and to decreasing bypass after PARHM's implementation, although the number of post-periods is small. There were no significant differential changes in the level or trends for hospital bypass related to PARHM, except for any elective surgery among patients from Cohort 3 HSAs, which showed a statistically significant relative decrease in trend of −4.57 percentage points (95% CI: −8.73 to −0.42) compared to control HSAs (Table 2).

3.3 | Risk-Stratified Analysis

We evaluated hospital bypass based on categories of surgical risk of intraoperative blood loss. We find that, except for patients from PARHM Cohort 3 HSAs, the estimated level and trend changes in hospital bypass were not significantly different between patients from PARHM and control HSAs (Table 2). For intermediate-risk elective surgery among patients from Cohort 3 HSAs, there was a statistically significant relative increase in level change of 11.17 percentage points (95% CI: 3.12–19.22) compared to control HSAs. However, the results were no longer significant after a Bonferroni correction for multiple comparisons.

3.4 | Sensitivity Analyses

To better understand if our primary definition of bypass (i.e., receiving care from a hospital in an HSA different from the patient's residence) influenced our results, we conducted a sensitivity analysis where we recategorized bypass based on driving distance (i.e., receiving care from a hospital other than the nearest hospital by driving distance from the patient's residence). We found no significant differential change in hospital bypass based on this alternative definition (Table S3). All other sensitivity analyses (i.e., removal of COVID-19 data, unadjusted model, patients from HSAs without inpatient care, FORHP definition of rural, system affiliated hospitals) produced null results (Table S3).

3.5 | Subgroup Analyses

Figure 2 shows that throughout the study period, hospital bypass rates are much higher among PARHM compared to control HSAs with CAHs, even before the model's implementation. Results were similar among Cohort 1 and Cohort 2 analyses, and Cohort 3 was omitted because there were no CAHs.

There were statistically significant relative level increases in hospital bypass for elective surgery among PARHM Cohort 1 and 2 HSAs of 28.45 percentage points (95% CI: 8.15–48.76) and 29.70 percentage points (95% CI: 12.54–46.86), respectively, compared to control HSAs with CAHs (Table 3). This change in level refers to an immediate shift in bypass rates following the introduction of PARHM. For patients from PARHM Cohort 1 and 2 HSAs, there were also significant relative trend increases in hospital bypass for elective surgery of 9.12 percentage points (95% CI: 2.45–15.79) and 21.65 percentage points (95% CI: 7.07–36.23), respectively, compared to patients from control HSAs Table 3. This change in trend refers to an alteration in the trajectory or slope of bypass rates following the introduction of PARHM. This change in trend represents how the rate of change in the outcome variable has been affected by PARHM, as opposed to an immediate shift in its level. Analyses across different payers were not statistically significant (Table 3).

4 | Discussion

To our knowledge, this study provides the longest longitudinal analysis to date (7 years) on rural hospital bypass rates and is the first to investigate the association between global budgets and changes in rural hospital bypass rates. Consistent with previous research, we found bypass rates ranging from 45%–94%, and generally increasing over time [3, 41]. In most analyses, we observed no statistically significant changes in rural hospital bypass for elective surgery attributable to PARHM.

However, among patients living in HSAs served by CAHs, PARHM participation was associated with a significant relative increase in bypass rates compared to control HSAs. The observed relative increase appears to be driven by a ceiling effect of hospital bypass near 100% among patients from PARHM HSAs with a CAH compared to a decrease in hospital bypass among patients from control HSAs with a CAH. This indicates that the observed difference may not be entirely the result of PARHM.

Bypass rates may have been higher among patients in PARHM Cohort 1 HSAs—especially those with CAHs—because hospitals in these areas tended to be smaller, were more likely to be CAHs, had fewer employees, and had worse financial characteristics, such as lower total margin [42]. The substantial decrease in hospital bypass in the post-treatment period for non-participating PARHM-eligible CAHs could be influenced by several external factors. For example, these CAHs may have implemented independent quality improvement or service expansion initiatives that attracted more patients locally, reducing the

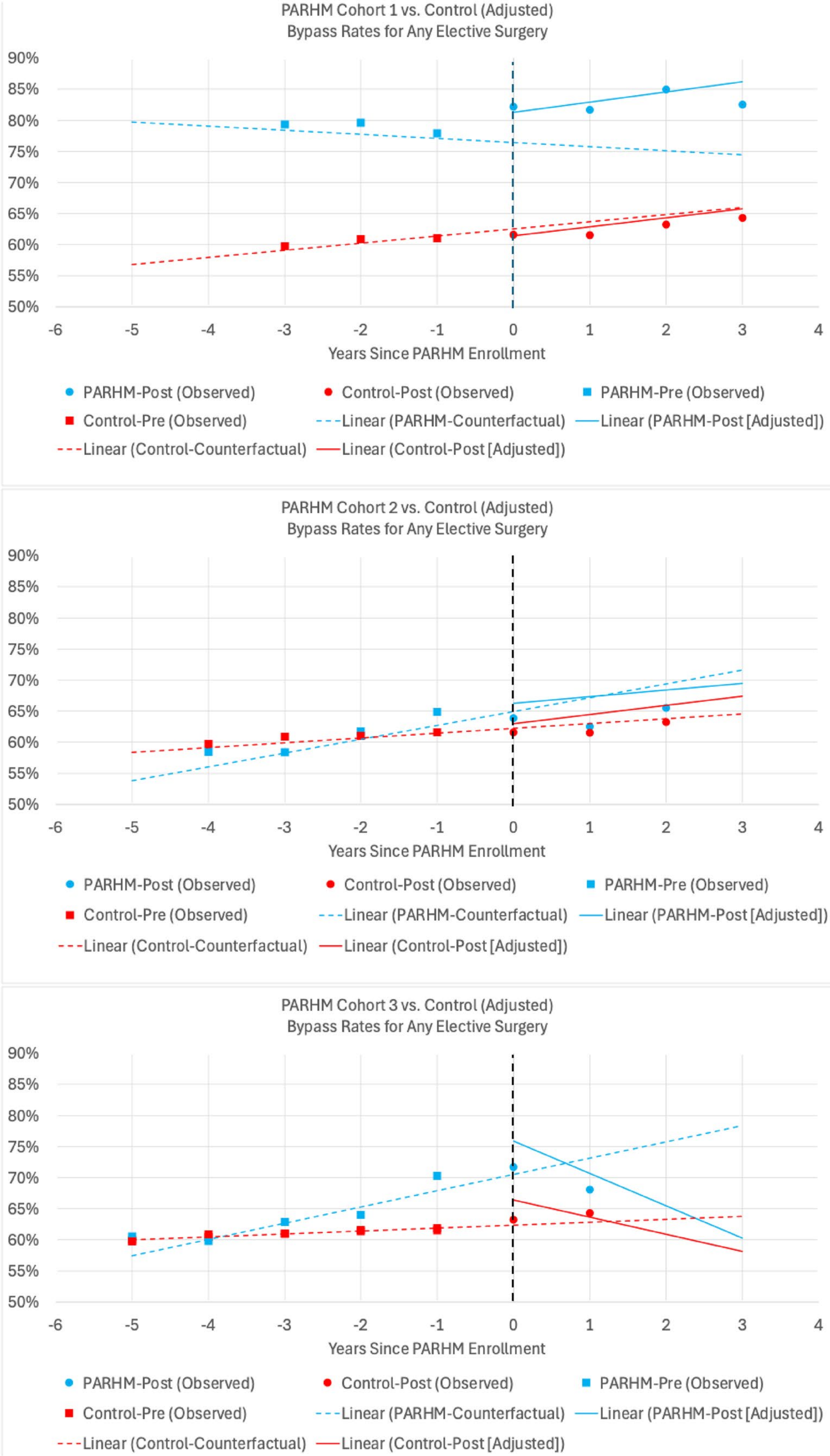

FIGURE 1 | Legend on next page.

TABLE 2 | Comparative interrupted time series estimated change in rural hospital bypass for elective surgeries attributable to PARHM (Adjusted).

Hospital bypass: % points (95% CI)	PARHM Cohort 1 $N = 141,163$	PARHM Cohort 2 $N = 156,258$	PARHM Cohort 3 $N = 149,931$
Any elective surgery			
Change in level	5.96% (−4.63–16.55)	0.53% (−8.17–9.22)	1.33% (−7.20–9.85)
Change in trend	2.01% (−4.58–8.61)	−1.85% (−8.83–5.13)	−4.57% (−8.73 to −0.42)*
Very high risk			
Change in level	18.74% (−2.96–40.44)	17.53% (−1.67–36.74)	1.09% (−6.40–8.58)
Change in trend	7.69% (−2.18–17.56)	3.08 (−3.56–9.71)	1.43 (−4.50–7.35)
High risk			
Change in level	0.94% (−8.73–10.61)	2.80% (−5.77–11.38)	2.67% (−8.36–13.70)
Change in trend	0.26% (−7.34–7.91)	0.08% (−10.09–10.25)	1.34% (−5.05–7.73)
Intermediate risk			
Change in level	12.17% (−0.41–24.74)	−0.06% (−10.59–10.47)	11.17% (3.12–19.22)*
Change in trend	5.17% (−3.70–14.04)	−1.49% (−10.97–8.00)	2.83% (−5.74–11.42)
Low risk			
Change in level	5.27% (−15.13–25.66)	−10.32% (−24.92–4.29)	−4.80% (−25.74–16.13)
Change in trend	−3.57% (−14.05–6.91)	−6.55% (−17.13–4.04)	−5.21% (−14.88–4.46)

Note: Adjusted for the following patient-level covariates: Elixhauser Comorbidity Index; Age; Sex; Race.
*Significant at $p < 0.05$ level.

need for rural hospital bypass. In addition, changes in referral patterns, affiliations, or informal care networks may also have contributed to the observed reduction in bypass among these CAHs. Among Cohort 1 HSAs, only 33% were system-affiliated versus 90% of non-participating PARHM-eligible CAHs [17]. Formal relationships with larger systems may have facilitated changes allowing more local surgical services.

There are longstanding concerns about how to deliver hospital-based services effectively and efficiently to rural-dwelling populations. Although patients may prefer to receive care locally, a large body of evidence indicates that certain surgical procedures exhibit a volume–outcome relationship in which there is an association with better outcomes for patients undergoing particular procedures at a high-volume hospital [43]. A concern is that many rural hospitals lack the volume, staffing, and resources to sustain large surgical programs but may still be reluctant to transfer patients to higher-volume hospitals [44, 45]. This may be because transferring patients would cause hospitals to forgo revenue from high-margin services that can help cover their operating costs—especially salient for rural hospitals that have relatively high fixed costs, low volumes, and struggle financially.

Considering these findings, there is a need for creative solutions to balance local provision of surgical care with the fact that effective and efficient surgical care is facilitated by centralization in large-volume centers, which are usually located outside rural areas. Conceptually, global budgets might influence how hospitals organize service lines and refer patients out for care. While PARHM did not explicitly aim to regionalize care for rural populations, prospective global budgets incentivize decreasing inpatient utilization. This may explain why an increase in hospital bypass could be expected after PARHM's implementation. On the other hand, PARHM aimed to better align care with community needs, which could also lead to the expansion of some services. In fact, service line "rightsizing" has been a strategic objective of PARHM through hospital transformation plans [16–18]. However, service line rightsizing may not yield immediate savings because it may be difficult for hospitals to reduce long-term capital costs. Hospitals also might be reluctant to discontinue service lines given uncertainty about long-term demand and the

FIGURE 1 | Comparative Interrupted Times Series for Rural Hospital Bypass for Any Elective Surgery Before and After the Pennsylvania Rural Health Model (PARHM). This figure illustrates the impact of the PARHM on bypass over time, comparing patients from Hospital Service Areas (HSAs) with PARHM-participating hospitals (blue) to patients from HSAs with a non-participating PARHM-eligible hospital (red). The squares and circles represent unadjusted point estimates in the pre- and post-periods, respectively. The dotted and solid lines represent adjusted trend lines from the pre- and post-periods, respectively (e.g., differences between observed and expected findings are due to risk adjustment or something similar). The figure shows a non-significant change in bypass immediately after PARHM entry, indicated by a change in level. In addition, the slope of the bypass trend does not change significantly, indicating a similar rate of change in the post-intervention period for the intervention group (blue) compared to the comparison group (red). The vertical line at zero on the *x*-axis represents the year relative to enrollment in PARHM for each cohort (Cohort 1: 2019; Cohort 2: 2020; Cohort 3: 2021).

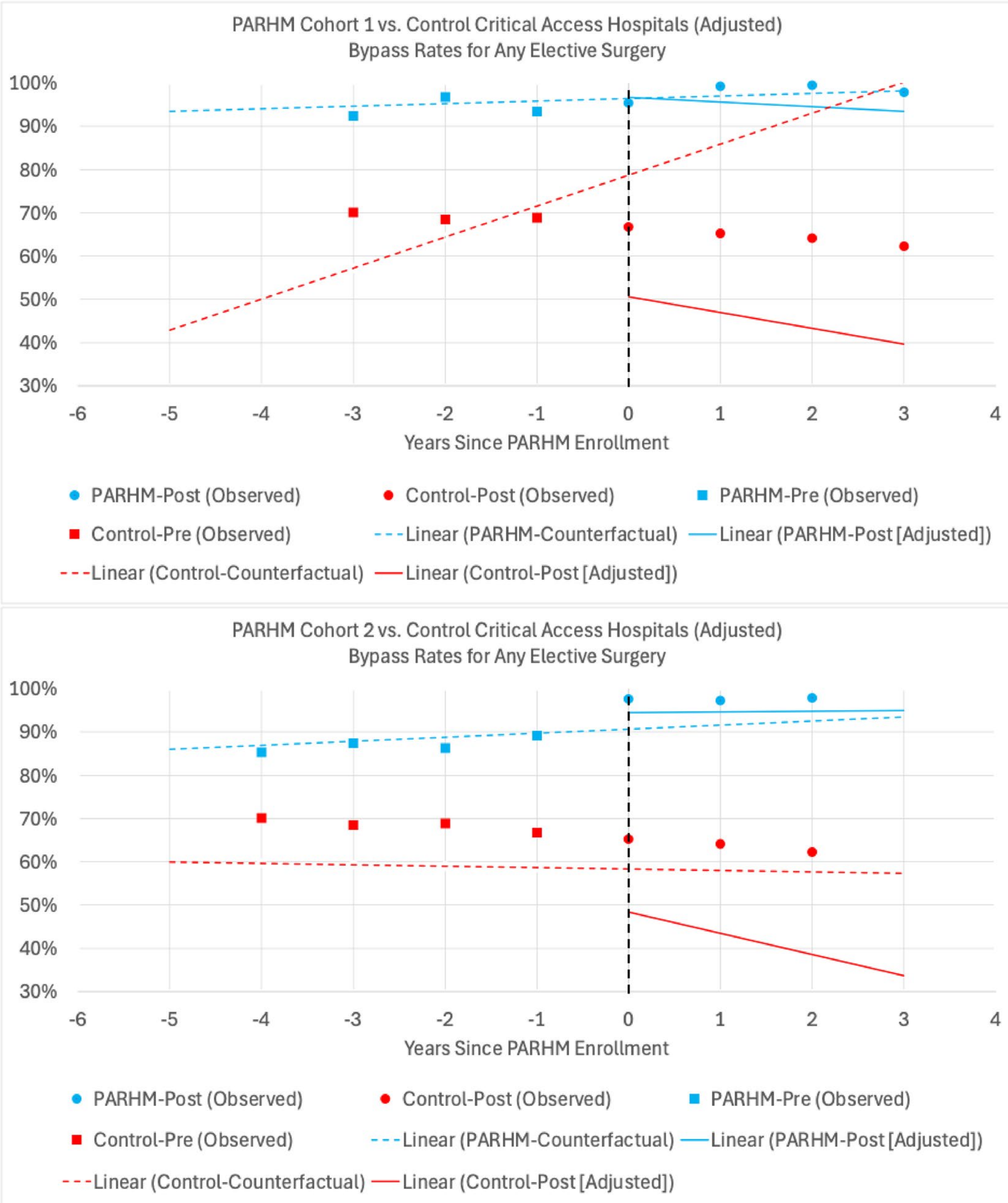

FIGURE 2 | Comparative Interrupted Times Series for Rural Hospital Bypass for Any Elective Surgery among Critical Access Hospitals (CAHs) Before and After the Pennsylvania Rural Health Model (PARHM). This figure illustrates the impact of the PARHM on bypass over time, comparing patients from Hospital Service Areas (HSAs) with PARHM-participating CAHs (blue) to patients from HSAs with a non-participating PARHM-eligible CAHs (red). The squares and circles represent unadjusted point estimates in the pre- and post-periods, respectively. The dotted and solid lines represent adjusted trend lines from the pre- and post-periods, respectively (e.g., differences between observed and expected findings are due to risk adjustment or something similar). The figure shows a significant relative increase in bypass immediately after PARHM entry, indicated by a change in level. In addition, the slope of the bypass trend does not significantly change in the intervention group (blue) and decreases in the comparison group (red), indicating a relative increase in the rate of change in the post-intervention period for the intervention group (blue) compared to the comparison group (red). The vertical line at zero on the *x*-axis represents the year relative to enrollment in PARHM for each cohort (Cohort 1: 2019; Cohort 2: 2020). Cohort 3 is omitted because it did not include any CAHs.

high cost of re-establishing services. Consequently, PARHM-participating hospitals may have decided to expand, contract, or make no changes to their surgical service lines based on their assessment of costs and community needs.

Importantly, the exclusion of payments for professional services from PARHM's global budget methodology may have led to conflicting financial incentives for physicians, who continued to have volume-based incentives, and PARHM hospitals, which did not. Because referral of patients is largely controlled by physicians, not hospitals, the persistence of volume-based incentives for physicians may have blunted the effects of PARHM on hospital bypass. Alternative approaches might include expanding the global budgets to cover professional services, providing

TABLE 3 | Subgroup analyses for difference-in-differences estimates for hospital bypass per person-year pooled and across individual cohorts (adjusted).

Hospital bypass: % points (95% CI)	**PARHM Cohort 1 $N = 141,163$**	**PARHM Cohort 2 $N = 156,258$**	**PARHM Cohort 3 $N = 149,931$**
Hospital type: CAH			
Change in level	28.45 (8.15–48.76)*	29.70% (12.54–46.86)*	N/A
Change in trend	9.12 (2.45–15.79)*	21.65% (7.07–36.23)**	N/A
Hospital type: PPS			
Change in level	4.85% (−7.20–16.90)	1.93% (−3.12–6.98)	2.74% (−5.08–10.57)
Change in trend	2.51% (−3.55–8.57)	−1.22% (−8.92–6.48)	1.15% (−3.63–5.94)
Payer: Medicare			
Change in level	4.78% (−3.42–12.98)	4.22% (−0.82–9.26)	1.00% (−4.77–6.77)
Change in trend	2.25% (−1.61–6.11)	0.51% (−3.45–4.47)	2.05% (−0.91–5.01)
Payer: Medicaid			
Change in level	0.93% (−1.94–3.79)	−2.18% (−4.61–0.25)	1.33% (−0.70–3.35)
Change in trend	−0.28% (−2.19–1.62)	−0.10% (−1.01–1.21)	0.84% (−0.23–1.92)
Payer: Commercial			
Change in level	0.68% (−2.70–4.06)	0.81% (−3.14–4.75)	1.14% (−1.86–4.14)
Change in trend	0.25% (−2.69–3.19)	−1.46% (−5.02–2.09)	−1.20% (−4.24–1.84)

Note: Adjusted for the following covariates: Elixhauser Comorbidity Index; Age; Sex; Race; COVID-19 Hospitalization Rates. All analyses in this table were run using a stacked DID allowing for differential pre-treatment trends. In the PPS analysis there were two Cohort 1 HSAs, six Cohort 2 HSAs, five Cohort 3 HSA, and 30 control HSAs. In the CAH analysis there were three Cohort 1 HSAs, two Cohort 2 HSAs, zero Cohort 3 HSA, and 10 control HSAs.
*Significant at $p < 0.05$ level.
**Significant after Bonferroni correction ($p < 0.004$).

financial support for surgical workforce development, and including access to common surgical services as a programmatic goal through the hospital transformation plans.

Although we did not see overall changes in rural hospital bypass under PARHM, we did see some evidence of a differential increase in rural hospital bypass among CAHs. This finding is potentially important, as critical access hospitals are small facilities and often have the lowest volume of surgical cases. Further research is needed to understand factors at the patient, physician, and hospital levels that might have led to changes in rural hospital bypass in communities served by CAHs. It will also be important to understand the consequences of changes in hospital bypass on patient outcomes. While bypassing a rural hospital is often interpreted as a negative outcome—suggesting potential gaps in local access or quality—bypass can also reflect a deliberate strategy to consolidate specialized services in higher-volume facilities [46, 47]. For example, referring patients to larger and better-resourced flagship centers may allow for more coordinated, higher-quality care for complex cases and enhance outcomes, even if it means some patients travel further [48]. Thus, it remains important to assess if changes in bypass rates in CAHs affected patient outcomes.

4.1 | Limitations

Our study has several limitations. First, selection bias is a potential concern because PARHM was voluntary and prior research identified baseline financial differences between participating and non-participating hospitals and reasons for joining the Model [42, 49]. However, one of the strengths of the CITS design is that HSAs act as their own control and that the design controls for baseline trend differences between treatment and control HSAs. In addition, we used propensity score weighting to account for factors that could be related to model participation and pre-treatment trends. However, we cannot rule out that unmeasured time-varying differences between participating and non-participating hospitals affected our results [50]. Second, COVID-19 may have differentially affected the treatment and control hospitals after the implementation of PARHM. To address this, we adjusted for COVID-19 hospitalization rates in our models and then conducted a sensitivity analysis removing data from the years 2020–2022. Our prior research showed no statistically significant differences in COVID-19 hospitalization rates between PARHM-participating and eligible non-participating hospitals [51]. However, hospitals' varied responses to COVID-19, including decisions about elective surgeries, may have been influenced by factors such as financial status, and thus it could be endogenous with PARHM participation. Third, we tracked hospitals for a maximum of 4 years after they joined the program, which limited our ability to observe longer-term changes. Transformations such as closing or launching hospital service lines require significant time and planning. Hospitals must assess unmet community health needs, prepare physical and operational space for new services, and recruit or train the necessary staff—processes that often unfold gradually. A follow-up period of 2–4 years, depending on the cohort, may be insufficient for hospitals to fully implement their planned changes. Fourth, it is also possible that the intervention as implemented was too weak, and no amount of follow-up would demonstrate significant results. The global budget target was 75% of eligible net patient revenue in 2019 and 90% thereafter for participating hospitals, but these targets were not met by 40% of hopsitals [17]. For global budgets to be effective, they may need to cover 100% of revenue. Fifth, a fundamental issue in analyzing small state-level programs like PARHM is sample size. In this case, only 18 out of 65 eligible hospitals participated in the model. This limits the power of our study to detect small, but potentially relevant, differences. Sixth, findings from our study may not be generalizable to the national rural population or rural hospitals in other states. However, population demographics and rural hospitals in Pennsylvania are similar to those of rural communities elsewhere in the country, and rates of bypass in this study were similar to those observed in studies conducted elsewhere [2, 3, 7, 52].

5 | Conclusions

Up to 4 years post-implementation of PARHM, there were not significant differential overall changes in hospital bypass between patients from HSAs with PARHM-participating hospitals compared to patients from control HSAs. However, subgroup analyses revealed a differential increase in bypass rates among residents of HSAs served by critical access hospitals. Rural hospital bypass has important implications for the access to care and financial viability of rural hospitals. Future research should be devoted to understanding any changes in drivers for rural hospital bypass under global budgets, both quantitatively and qualitatively. It will be important for policymakers to understand this if considering global budgets as a policy solution.

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Data Availability Statement

The data that support the findings of this study are available from Pennsylvania Health Care Cost Containment Council. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from https://www.phc4.org/browse-our-data/ with the permission of Pennsylvania Health Care Cost Containment Council.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.