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DISPARATE IMPACTS OF PERFORMANCE FUNDING RESEARCH INCENTIVES ON RESEARCH EXPENDITURES AND STATE APPROPRIATIONS

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Introduction

Public four-year universities in the United States, which are subsidized by government appropriations, typically have institutional missions centered on a combination of research, teaching, and service (Rhoten & Calhoun, 2011). The research function of higher education is critically important to not only institutional prestige but also economic development (e.g., Eid, 2012; Guisan, 2005; Jongbloed et al., 2008; Volkwein & Sweitzer, 2006). State policymakers look to colleges and universities to foster research activities as a way to improve innovation and economic development within their individual states, and a growing number of states have begun to increase their financial commitment to efforts designed to expand the research capacity of their public colleges and universities (Toutkoushian & Paulsen, 2016).

Performance-based funding (PBF), which has grown in popularity and is currently used by two-thirds of states, ties a portion of a public college or university's level of state appropriations to institutional outcomes (Ortagus et al., 2020). The metrics states use to evaluate institutional performance most often include student outcomes, such as progression toward a degree and degree production, but an increasing share of PBF systems are focusing specifically on a given institution's research activities (Rosinger et al., 2020). Research metrics for PBF-adopting states have varied over the years but often include institutions' research expenditures from externally funded grants and broad measures of research and development (R & D) expenditures. Slightly fewer than half (19) of the 41 states that have adopted PBF over time have included research-oriented metrics within their PBF formulas (authors' calculations).

Research incentives in PBF systems provide incentives for institutions to support research activities by tying state appropriations to research-oriented expenditures and outcomes in alignment with the institutional missions of public research universities (Burke, 1998; Miller, 2016; Snyder & Boelscher, 2018). But PBF can increase the tension between policymakers' desire to hold institutions accountable and the financial realities of already under-resourced colleges or universities (Boland, 2020; Hillman & Corral, 2018).

Due to the unequal funding distribution of public higher education, minority-serving institutions (MSIs), in particular, often receive insufficient resources to maximize their research capabilities and are left with limited financial flexibility when compared to predominantly-white institutions (Boland & Gasman, 2014; Cunningham et al., 2014). PBF policies typically lead to funding systems in which already-advantaged institution types receive a disproportionate share of funding and underfunded institutions, such as MSIs, are asked to continually do more with less (Hagood, 2019; Hillman & Corral, 2018; Li et al., 2018; Ortagus et al., 2020) and have a higher share of funding at stake in PBF systems (Jones et al., 2017). For MSIs, the unique mission of these institution types related to serving targeted student populations is often overlooked in PBF metrics (Gasman et al., 2017).

While a large body of previous research has focused on the intended and unintended consequences of PBF on students' academic outcomes (Hillman et al., 2014; Ortagus et al., 2020; Umbricht et al., 2017), PBF policies incentivizing research activities have a substantive impact on institutional behavior but have yet to be studied in the academic literature. To examine the impact of PBF with research incentives on the behaviors of public four-year colleges and universities with a focus on MSIs, this study is guided by the following research questions:

1. To what extent do PBF research incentives influence the level of research expenditures at public four-year institutions?
2. To what extent do PBF research incentives influence the total state appropriations received by public four-year institutions?
3. Does the influence of PBF policies with research incentives on research expenditures or total state appropriations vary according to an institution's MSI status?

Literature Review

Research incentives featured less prominently than student-oriented measures of institutional performance in early PBF policies, emphasizing states' strategic investment in degree completion over institutional prestige indicators (Burke 1998; Toutkoushian & Danielson, 2002). However, PBF policies have linked a portion of state appropriations to research outcomes for certain institutions since the 1990s. Roughly two-thirds of states that operated *early* PBF systems included a research metric for at least one institution (Burke & Serban, 1998; Dougherty & Natow, 2015), and states have incorporated measures of research activity into more recent PBF policies at a similar rate (Rabovsky, 2012). As one example, every university in Florida's State University System is able to choose whether or not to include research expenditures as one of its ten performance metrics (Cornelius & Cavanaugh, 2016; Snyder & Fox, 2016). PBF policies in other states, such as Kansas, Maine, and Montana, have tied state appropriations to research activity for a small subset of four-year institutions within each state (Snyder & Boelscher, 2019).

Research Expenditures at Public Four-Year Institutions

The level of institutional expenditures on research activities plays a pivotal role in the extent to which a college or university is able to increase its ranking or institutional prestige (Morse & Brooks, 2020; Volkwein & Sweitzer, 2006), research productivity (Dundar & Lewis, 1998; Eid, 2012), and other important outcomes related to institutional efficiency and effectiveness (Powell et al., 2012; Robst, 2001). For example, research and development expenditures in higher education in European countries were positively related to innovation (Pegkas et al., 2019). Guisan (2005) pointed out that research expenditures at universities in the U.S. greatly contribute to regional development and solidifies a comparative advantage relative to the majority of European regions and countries.

The level of a given institution's reliance on research expenditures is largely dependent on its available revenue sources and stability in funding (Leslie et al., 2012). Historically, private four-year universities have higher levels of research expenditures than public colleges and universities (Blasdell et al., 1993). Moreover, private universities have accelerated their spending on research activities and have experienced corresponding advantages in institutional prestige over the years (Lau & Rosen, 2016), including when it comes to recruiting faculty (Alexander, 2001; Rippner & Toutkoushian, 2015). By analyzing the Higher Education Research and Development (HERD) survey data collected by the National Science Foundation (NSF), Britt (2013) noted that institutions' research and development (R&D) expenditures are derived primarily from the federal government and only about six percent were funded by state and local governments. The author also found that the majority of R&D funding was spent in disciplines of medical sciences and biological sciences by a small group of research universities.

The second Morrill Act of 1890 provided funding for many Historically Black Colleges and Universities (HBCUs) to be established as land-grant colleges, while other MSIs are granted MSI status by the U.S. Department of Education based on their student composition (Cunningham et al., 2014). However, MSIs have been underfunded in ways that restrict their ability to expand their research expenditures and build their research capacity (Gasman & Commodore, 2014). In 2010, MSIs only spent $1,638 on research and public service expenditure per full-time equivalent (FTE) student, which was only a quarter of the amount ($6,202) spent by non-MSIs (Cunningham et al., 2014). Prior research attributes these wide disparities in funding to unequal state funding mechanisms, including performance-based funding (Hillman & Corral, 2018; Jones et al., 2017; Li et al., 2018), and insufficient support from federal R & D funds (Boland & Gasman, 2014; Matthews, 2011; National Center for Science and Engineering Statistics, 2021). In recent years, a growing number of MSIs have sought to increase their research capacity as a way to mimic the research-intensive, prestige-seeking universities that receive a disproportionate share of state funding (Doran, 2015).

Due to the institutional mission of MSIs focused on empowering racially marginalized students before implementing prestige-seeking behaviors, MSI faculty often carry larger teaching and advising loads and receive lower levels of research support when compared to non-MSI faculty (Clark et al., 2016). With an increasing number of MSIs seeking to become research-intensive institutions (Doran, 2015), it is critical to understand the potential impact of state-level policies on research expenditures for MSIs. While previous research has centered around the impact of PBF on student success at MSIs (Boland, 2020; Hu, 2019), little is known regarding the extent to which PBF policies with research-oriented metrics may alter institutional expenditure patterns at MSIs or the extent to which these policies impact state appropriations these institutions receive.

Incentivizing Research Activities with Performance-Based Funding

To incentivize research activities, many European countries (e.g., Belgium, Italy, Norway, Sweden) have adopted PBF with varying provisions related specifically to research activities. In general, previous research has found that PBF adoption within European countries is positively related to research productivity for colleges and universities (Aagaard et al., 2015; Cattaneo et al., 2014; Checchi et al., 2019; Sīle & Vanderstraeten, 2018; Vanecek, 2014). However, the impact of PBF on research productivity can vary greatly depending on the academic discipline (Engels et al., 2012) and selectivity of the institution (Abramo et al., 2011), which can exacerbate already-existing inequities among colleges and universities (Mateos-Gonzalez & Boliver, 2019).

In the United States, Indiana's research incentive was the first metric used to measure performance in the state's PBF program (Umbricht et al., 2017), whereas other PBF states have incorporated research-oriented metrics into existing systems. Prior studies have examined the relationship between PBF adoption and university research activity and expenditures, despite their common drawback of not actually identifying PBF programs with research incentives. Early PBF programs in Florida and South Carolina coincided with increases in externally funded research activity (Shin & Milton, 2004). Using spline linear modeling to explain variation in research funding at four-year colleges and universities from 1997 to 2007, Shin (2010) determined that institutional characteristics, rather than PBF policies, contribute to institutional differences in revenue growth from federal research grants and contracts. Kelchen and Stedrak (2016) reported that PBF adoption was not related to expenditures for research for all four-year institutions; however, PBF policies were associated with decreases in annual research spending of less than one percent for research universities specifically. Spending of gift, grant, and contract revenues by research universities in PBF states was also associated with minimal decreases in state appropriations (Rabovsky, 2012).

State policymakers' desires to measure efficiency and productivity can create tension with measures of institutional performance given the complexity of varying institutional missions (Jones, 2015). Upon the adoption of any performance-oriented programs, including PBF and other performance budgeting programs, research funding has been found to increase at flagship universities specifically, while non-flagship universities experienced decreases in both research funding and publication activity (Payne & Roberts, 2010). Taken together, previous literature related to PBF adoption and research-related priorities offers mixed findings due in part to the misalignment between the policy lever and outcomes being examined (i.e., the metrics of PBF systems vary across states and may not incentivize research-related outcomes). In this study, we offer the first evidence to date related to the direct impact of PBF research incentives and the subsequent research activities and level of state appropriations among PBF-adopting institutions.

Theoretical Framework

The theoretical framework of this study is guided by principal agent theory, which suggests that the principal (state government) pays the agent (public college or university) to carry out an objective (Jensen & Meckling, 1976; Spence & Zeckhauser, 1971). In the case of PBF policies that center research-oriented metrics, the objective relates to investing in (and ultimately producing) research in ways that can improve the prestige of the institution and a given state's economic environment. Importantly, the logic of any principal-agent model rests upon the assumption that the outcomes of the agent (e.g., investments in research activities) must be observable and measurable by both the principal and agent.

For external resource providers, such as the state government, the extent to which they can influence a public institution's behavior depends on whether the resource being provided is deemed critical and not obtained easily by another funding source (Emerson, 1962; Harnisch, 2011). In addition, Rabovsky (2012) has reported that shifts in how states allocate resources will likely lead to the adoption of new strategies by colleges and universities seeking to enhance their performance according to the prescribed funding formula. Under a resource dependence perspective, any public colleges or universities that rely heavily on state appropriations may alter their institutional behaviors in response to changes in their state's funding criteria, such as the introduction of a PBF metric incentivizing research activities.

PBF policies are typically created to directly tie at least a portion of public institutions' state funding to their academic outcomes, with a particular focus on the intended outcomes of student retention and degree completion (Ortagus et al., 2020). Given that prior work has reported that traditional PBF systems disadvantage MSIs when compared to non-MSIs (Hillman & Corral, 2018; Jones et al., 2017), the introduction of additional metrics in PBF programs that incentivize research and prestige-seeking behaviors may exacerbate already-existing inequities facing MSIs in PBF-adopting states.

The logical rationale of principal-agent theory coupled with a resource dependence perspective (e.g., Pfeffer & Salancik, 1978) suggests that public research universities, which rely heavily on state funding allocations, are likely to respond to the implementation of PBF with research-oriented metrics by reorganizing their activities in search of external resources and thereby increasing their research output and expenditures. However, the historic underfunding of MSIs may limit their capacity to increase research infrastructure and meet their PBF goals. Given these dynamics, this study explores what happens after PBF policies with research incentives are introduced, focusing specifically on the institutional responses of public research universities and the potential inequities facing MSIs within these PBF systems.

Methods

Data and Sample

In this study, we use institution-level data from Integrated Postsecondary Education Data System (IPEDS), and state-level data from the Council of State Governments (CSG) and the National Association of State Budget Officers (NASBO). We identified every public university in the U.S. subject to a PBF program that includes research incentives by systematically analyzing more than 1,500 state budget or policy documents between 1997 and 2020 (Authors, 2019, 2020). These documents include state appropriation bills, higher education budgets, policy reports, personal communication with higher education policymakers, and other first-hand sources that provide information for the years of operation, amounts of funding at stake, sectors and institutions affected, and performance metrics of PBF policies. The analysis window for this study is 2002 to 2018, which is when data on research expenditures in IPEDS aligns with the years from the PBF dataset.

To select institutions with comparable mission and research capacity, we restricted our sample to public four-year universities that were classified as doctoral research universities or master's colleges and universities based on the 2000 Carnegie classification. We include master's institutions because numerous master's institutions are eligible to include PBF research incentives in PBF-adopting states (e.g., Tennessee and Florida). We excluded institutions that did not offer any undergraduate programs or closed between 2002 and 2018. To examine the influence of PBF with research incentives on institutional research expenditures, we excluded institutions in states that either adopted or abandoned PBF with research incentives in the first two years (2001-02, 2002-03) or the last two years (2016-17, 2017-18) as a way to ensure at least two years of pre- and post-treatment observations, respectively (Wooldridge, 2002). The final panel dataset consisted of 17 years of observations from 394 public universities (n = 6,629), with data for some years missing for 3.8% of institutions. Finally, we created a minority-serving institution (MSI) indicator and created an MSI subgroup (n = 1,933) and a non-minority-serving institution (NMSI) subgroup (n = 4,696) after identifying an institution's MSI eligibility in 2020 via U.S. Department of Education data. Institutions defined as MSIs include HBCUs and any colleges or universities eligible to be Primarily Black Institutions and Hispanic Serving Institutions, Asian American and Native American Pacific Islander-Serving Institutions, Native Hawaiian-Serving Institutions, and Native American-Serving Nontribal Institutions.

Variables

The dependent variables for this study are (1) the amount of research expenditures transformed using a natural logarithm, (2) the relative share of research expenditures relative to total expenditures, and (3) the amount of state appropriations transformed using a natural logarithm. The treatment variable is a binary indicator of an approved PBF policy that includes research incentives, with the treatment turning on or off at the institution level. By approved PBF policy, we mean a policy through which funds could be allocated based in part on institutional performance existed in state legislation or, if a state higher education agency allocated state dollars to institutions, existed in board documents. The treatment variable is coded as 1 for institutions subject to PBF policies with research incentives, and it is coded as 0 if PBF is not in place or the PBF policy does not have research incentives for the institution. Between 2002 and 2018, 63 institutions across 13 states were subject to approved PBF policies that included research incentives (see Figure 1 and Appendix A).

See Figure 1. PBF Research Incentives in Place by State for Eligible Institutions

Because the binary treatment variable only captures adoption and potentially masks the complexity of PBF policies (Ortagus et al., 2020), we used variations of the treatment indicator in additional model specifications to capture (1) if the PBF research incentives were actually funded and (2) if PBF-adopting institutions were able to self-select or "opt in" to include research incentives as part of their PBF formula. Among institution-year observations subject to PBF research incentives, 83.7% of the observations were actually funded and coded as 1 for the first alternative specification. Institutions with no PBF research incentive or a PBF research incentive that was not actually funded were coded as 0. The treatment variable for the second alternative specification is coded in a categorical manner, indicating whether colleges and universities are granted autonomy to self-select PBF metrics. PBF-adopting institutions that were able to self-select or opt in for certain metrics (coded as 2 in this additional specification) represent 34.6% of all institution-year observations subject to PBF policies with research incentives. Institutions subject to PBF policies that mandated the use of all incentives were coded as 1. Institutions with no PBF research incentives were coded as 0.

Based on prior literature (e.g., Cunningham et al., 2014; Leslie et al., 2012; McClure & Titus, 2018), we controlled for both state- and institution-level covariates that could impact the level of research expenditures or state appropriations. We included two state-level covariates: state legislative control indicating if the same party held both the legislative chamber and the governorship and the percentage of state annual appropriations allocated to higher education (McLendon et al., 2009). Institution-level variables included institutional characteristics (e.g., size, location, affiliated hospital, medical degree conferring status, MSI status), percentage of applicants admitted as a proxy for selectivity, revenues (e.g., revenue from tuition and fees per FTE student, revenue from federal, state, local/private contract and grant per FTE, respectively), and instructional cost per FTE as a proxy for competing institutional expenses. To examine the impact of PBF policies with research incentives on total state appropriations, we also controlled for the presence of any PBF policy for the four-year sector (including PBF systems that did not include research incentives). Institution-level variables came from the National Center for Education Statistics' Integrated Postsecondary Education Data System. All dollar values were adjusted for inflation and Appendix B lists all variables and their sources used in our analyses.

Empirical Strategy

To estimate the average treatment effect of PBF research incentives on institutional research expenditures and state appropriations (our first two research questions), we used a generalized difference-in-differences (GDiD) model, which allows the treatment to turn on or off (as appropriate) for the individual institution between 2002 and 2018 (Angrist & Pischke, 2009). Specifically, the GDiD estimator (δ_1) was used to compare the difference in the outcomes between treated and untreated units after the adoption of PBF research incentives and then subtract the difference in outcomes before the adoption of PBF research incentives. Formally, we used ordinary least squares (OLS) regression in the model, holding covariates constant:

$$y_{ij} = \gamma_0 + \delta_1 treatment_{ij} + c_i + h_j + Z_{ij} + \gamma_{ij} + \varepsilon_{ij}$$

where y_{ij} represents the outcome variables at institution i in year j. γ_0 is an institution-specific intercept. *Treatment* is an indicator of the adoption of PBF research incentives for institution i in year j. δ_1 is the coefficient of interest. c_i represents the time-invariant institution-level fixed effect, and h_j represents the year fixed effect. By incorporating institution and year fixed effects, the model controlled for potential institution-specific effects over time as well as any time effects that were common across institutions in each year (Allison, 2009). Z_{ij} is a vector of state- and institution-level covariates described in the previous section. We also included institution-specific linear time trends (γ_{ij}) by interacting institution fixed effects with a continuous time trend (Furquim et al., 2020). To correct for heteroscedasticity and serially correlated error terms in panel data (Bertrand et al., 2004), we estimated robust standard errors in each model by clustering at the institution level.

Prior research on PBF policies has considered the number of years a policy has been in place, finding the impacts of PBF change the longer a system is in place (e.g., Li & Ortagus, 2019). This work suggests it may take institutions a year or two to respond to policy changes. To account for potential delays in institutions' response to PBF research incentives, we estimated additional specifications modeling a one-year lag and a two-year lag. Additionally, to examine whether institutional responses to PBF research incentives or level of state appropriations institutions receive differ based on an institution's MSI status (our third research question), we estimated the equation identified above for MSIs and NMSIs subsample separately.

To better account for the impact of PBF research incentives on institutional research expenditures and state appropriations, we selected multiple comparison groups of untreated institutions to construct counterfactual situations of institutional responses in the absence of PBF research incentives (Meyer, 1995). The first comparison group was restricted to 206 public four-year universities that were not subject to PBF research incentives in adjacent or neighboring untreated states (Cook et al., 2008). The second comparison group was a national sample of 306 public four-year universities that were not subject to PBF research incentives in all untreated states.

For the third comparison group, we selected statistically comparable institutions and accounted for differences across institutions by using Inverse Propensity Score Weighting (IPSW) and matching on pre-treatment covariates to improve residual balance and reduce bias from the regression model (Guo & Fraser, 2015; Ho et al., 2007). Specifically, we estimated a logit model predicting a college's probability of being subject to PBF research incentives conditional on all institution-level covariates in the base year. We addressed extremely small or large weights by trimming weights that fell outside of the threshold of the 1^{st} and 99^{th} percentiles in the distribution of weights (Austin & Stuart, 2015). After removing seven institutions with extreme propensity scores, the sample included 62 institutions that adopted PBF research incentives between 2004 and 2016 and 310 public four-year universities that were not subject to PBF policies with research incentives. The inverse of the propensity score used to weight each institution based on its likelihood of adopting PBF research incentives was then applied to all descriptive and regression analyses to estimate the average treatment effect of PBF research incentives on treated institutions for the third comparison group. Table 1 provides a descriptive summary of the variables for the treatment and comparison groups.

See Table 1. Descriptive summary of the variables

We applied the same procedure to the MSI and NMSI subsamples to create multiple comparison groups. Table 2 and Figure 2 present the balance for the unweighted and weighted groups, indicating that we met the common support assumption for the full sample and NMSI subsample. However, due to the small number of MSIs in the base year (n = 10), we did not meet the common support assumption using the IPSW approach. To create a comparison group of MSIs for the treated MSIs with PBF research incentives, we used a Coarsened Exact Matching (CEM) approach (see Hillman et al. (2014) and Hu et al. (2020) for examples of prior quasi-experimental work employing a CEM approach). Different from IPSW, CEM matches institutions based on select characteristics to improve balance for each variable in isolation rather than using one propensity score that was generated based on a set of covariates. In other words, CEM allows comparisons between treated and untreated observations that are comparable for each variable separately without reducing balance in other covariates, and this approach is particularly appropriate given the small sample size of MSIs (King & Nielsen, 2019; Wells et al., 2013).

See Table 2: Standardized differences of the unweighted and weighted sample & Figure 2. Estimated propensity scores Pre- and Post-weighting

We first tested the association between the exposure to treatment and each of the pretreatment covariates measured at baseline (i.e., the year of 2002). Based on its associated p value, we determine the inclusion or exclusion of covariates in the CEM model. Using this data-driven approach (Rosenbaum, 2002; Rosenbaum & Rubin, 1984), our CEM model includes medical degree granting status ($p = .005$), federal contract and grant revenue per FTE ($p < .001$), local/private contract and grant revenue per FTE ($p < .001$), state appropriations per FTE ($p = .037$), and instructional cost per FTE ($p = .029$). Second, we temporarily coarsened the four continuous variables at 33% breaks for each unique observation to ensure both reasonable covariate balance and sample size. Finally, the institutions were matched exactly on medical degree granting and the four coarsened variables. This procedure created 51 strata with unique numbers of cases. Five strata were matched yielding eight treated institutions and 14 untreated institutions, and other observations in unmatched strata were discarded (Iacus et al., 2009). After the CEM procedure, we used the original continuous values of the coarsened variables in our subsequent analysis. The L1 statistic, which is a measure of multivariate imbalance for variables in its continuous form (Iacus et al., 2009), for the full sample was 0.8 whereas the matched sample yielded an L1 statistic of 0.429. Table 3 presents that after the CEM procedure, the imbalance results for the continuous values of the variables have greatly reduced in the means and the marginal distributions, suggesting improved covariate balance (Blackwell et al., 2009).

See Table 3. Imbalance measurement of the Continuous Variables before and after CEM procedure for MSIs

Robustness Checks

We used several approaches to check the robustness of our analyses. First, we included multiple comparison groups with multiple pre- and post-treatment periods (typically examining a one- or two-year lead and lag) to examine if the results are consistent (Furquim et al., 2020; Meyer, 1995). The consistent pattern across model specifications suggested that the average treatment effects of PBF research incentives were robust regardless of comparison samples. Additionally, we ran alternative model specifications without the institution-specific linear time trends due to the risk of overcontrolling for unit-specific trends, which can greatly reduce the power needed to detect statistical significance (Furquim et al., 2020). The results of model specifications without the institution-specific linear time trends are largely consistent with the findings of our preferred models with IPSW or CEM adjustments.

We tested the treatment effect on the treated by capturing whether the PBF research incentive was *approved*, whether the PBF research incentive was *funded*, and whether institutions have the option to *opt in* to including the research incentives as part of their PBF system. In additional model specifications, we controlled for the proportion of PBF funding relative to total state appropriations as a continuous variable. Specifically, over three quarters of treated institution-year observations (n = 467) have less than 6% of state appropriations tied to performance metrics, with the majority of treated institutions with a higher PBF dosage clustered in the state of Tennessee (n = 63). The results controlling for PBF dosage are highly consistent with the results in our preferred model specifications.

Limitations

This study was subject to several limitations. First, according to Jaquette and Parra (2014), IPEDS finance data has inconsistencies for institutions in a parent-child reporting relationship. We excluded institutions as child records, which represents less than 1% of the sample, because their finance data were reported with the parent institutions. In all analyses, we used data disaggregated by the U.S. Department of Education's Office of Postsecondary Education ID. We also ran model specifications including institutions in a parent-child relationship. Across alternative outcome model specifications, our findings remain highly consistent, indicating that the point estimates were not sensitive to the parent-child data limitation. IPEDS data has other inherited limitations as the survey items have changed over time, and we chose to restrict our panel data starting from 2002 to balance data consistency and sample size (Aliyeva et al., 2018; Delta Cost Project, 2011; Jaquetta & Parra, 2014).

In addition, treatment with time-varying adoption between 2002 and 2018 can bias the estimator and the inclusion of institution-specific trends may not be sufficient to address potential biases (Goodman-Bacon, 2018). To address biases associated with a GDiD approach when there is time-varying treatment adoption, we followed recommendations by Callaway and Sant'Anna (2020) to estimate the group-time average treatment effects of PBF research incentives for institutions that had only one adoption between 2002 and 2018. We leverage the *did* package in R that allows for variation in treatment timing across multiple periods and the parallel trends assumption to hold conditional on covariates. This approach can be extremely flexible when determining control units to consider, and the treatment effect estimates do not suffer from biases associated with two-way fixed effects regressions with time-varying treatment adoption. The results for each group-time average treatment effects are largely consistent with our main analyses for the full sample (all tables displaying group-time average treatment effects are available upon request).

Results

Descriptive Results

Table 4 presents descriptive differences in the outcome variables between the treated group and comparison groups. Before weighting, treated institutions had larger research expenditures in total ($104.6 million) relative to comparable institutions in neighboring states ($73.6 million) and comparable institutions in the national group ($64.4 million). Accounting for the likelihood of adopting PBF research incentives, treated institutions had lower research expenditures ($93.3 million) than comparable institutions ($94.2 million) after weighting. The relative share of total institutional expenditures allocated to research was higher for treated institutions when compared to institutions in any comparison group before and after weighting. Similarly, regardless of weighting, the average amount of state appropriations for treated institutions was consistently higher than the average amount for institutions in any of the comparison groups.

See Table 4. Descriptive summary of dependent variable

GDiD Results

We report results based on the preferred model specifications for the full sample and MSI and NMSI subsamples, controlling for state- and institution-level covariates, institution-level and year fixed effects, and institution-specific linear time trends. Table 5 presents the treatment effect of PBF research incentives on research expenditures for the treated institutions. Consistently, the results indicate that PBF research incentives are not significantly related to the total amount of research expenditures or the relative share of total expenditures allocated to research for treated institutions in the full sample or the MSI and NMSI subsamples. Table 6 shows the relationship between funded PBF research incentives and research expenditures for the treated institutions, controlling for state- and institution-level covariates. Even when the PBF research incentives are actually funded, the total amount of research expenditures and the relative share of total expenditures allocated to research were not significantly impacted by PBF research incentives in any of the samples, comparison groups, and lag model specifications. Additionally, our analysis of the total amount of state appropriations typically indicates that, funded or not, PBF research incentives are not statistically related to the total amount of state appropriations distributed to treated institutions relative to those institutions without PBF research incentives.

See: Table 5. Coefficients of PBF research incentives on research expenditure;
Table 6. Coefficients of PBF research incentives (funded) on research expenditure;
Table 7. Coefficients of PBF research incentives on state appropriations

Table 8 indicates the treatment effect of PBF policies with research metrics while accounting for specific design features of the PBF system. The results show that the option to self-select PBF research metrics as part of a PBF system is positively related to the relative share of research expenditures as well as total state appropriations for treated institutions. In other words, institutions that were able to self-select the metrics included in their PBF system experienced a 0.7% - 0.8% increase in the relative share of research expenditures in the no-lag and one-year lag model ($p < 0.05$). Table 8 also reveals that the adoption of self-selected PBF research incentives led to a 6.2% to 7% increase in treated institutions' total amount of state appropriations in the no lag model ($p < 0.05$).[1] In the one- and two-year lag model specifications, self-selected PBF research incentives are associated with an increase between 7.7% and 8.4% in treated institutions' total amount of state appropriations relative to untreated institutions nationwide ($p < 0.05$). The adoption of mandatory PBF research incentives is typically not related to research expenditures or state appropriations for the treated institutions, with the lone exception of a 0.6% reduction in the relative share of research expenditures in the no-lag model when compared with untreated institutions in neighboring states and the CEM comparison group ($p < 0.05$).

See Table 8. Coefficients of PBF research incentive types on research expenditure and state appropriations

Discussion

This national analysis of the impact of PBF research incentives provides a complex picture of what happens after a PBF-adopting state introduces research-or iented metrics, such as externally funded grants or institutional R & D expenditures. Contrary to previous research (e.g., Kelchen & Stedrak, 2016), we found that PBF policies with research incentives—regardless of whether they were merely approved or actually funded—were unrelated to the total amount of research expenditures or the relative share of total expenditures allocated to research for treated institutions. This particular finding is robust across MSI and NMSI subsamples. In addition, we found that PBF research incentives are not related to the total amount of state appropriations allocated to treated institutions, regardless of MSI status.

The only area in which there was a clear relationship between PBF research incentives and institutional research expenditures was when institutions could self-select or opt into including research incentives in their performance agreement with the state. In this case, there was an increase in the relative share of total expenditures that institutions allocated to research. We also found that institutions that were able to select own metrics, including research incentives, saw gains in total state appropriations. Universities that were able to self-select or opt into being evaluated based on research performance may have done so either because they wanted to place a higher priority on research than other metrics or they knew that the research performance goals were more easily attainable for their institution than other goals.

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[1] We followed Halvorsen and Palmquist (1980) and Kennedy (1981) to interpret the estimated impact of an indicator variable to be $\exp\delta\text{-}0.5\times\nu\text{-}1$, where δ is the estimated coefficient of indicator-coded PBF with research metrics adoption, and is the estimated variance of the estimated coefficient.

These findings raise questions for future research about the effects of required versus optional metrics in PBF systems, as self-selection may occur in unintended ways when institutions are given the option to choose their own metrics. If institutions select evaluation metrics on which they are likely to excel, they may improve in these particular areas but not necessarily in other areas in which state policymakers intend. For instance, future research might examine whether institutions that select a specific set of metrics see gains in those metrics while not showing similar gains (or even showing losses) in other metrics they did not select. Prior work indicates PBF policies in some states have become something akin to a "choose your own adventure" approach to state funding with institutions selecting one or more metrics on which they will be evaluated (Rosinger et al., 2020). This study demonstrates that such an approach may lead to gains, at least in research expenditures, in the specific metrics selected but also raises questions for future research about whether improvements will happen along other metrics as well.

In the case of research metrics, research universities that are positioned to compete for federal R & D funding may stand to gain the most under PBF systems that allow institutions to select research metrics as a component of their PBF funding formula. While a growing number of universities, including some MSIs (Doran, 2015), are engaging in striving activities that position themselves to win in competitions for research dollars, some institutions are better positioned to leverage their existing financial advantages to garner additional resources in the form of external research support (Cantwell & Taylor, 2015; Rosinger et al., 2016; Slaughter & Rhoades, 2004). Under PBF systems with research incentives, these already-advantaged institutions are also better positioned to see gains in state resources given that a portion of appropriations are linked to research expenditures and institutional efforts to secure external R & D funds. Similarly, those same institutions may see gains in federal R & D funds as a result of their efforts, leaving a select group of well-resourced institutions that stand to potentially gain both state and federal funds under these systems.

Less-resourced institutions might reorganize activities in pursuit of external funding and, in doing so, could see gains in state support, but such efforts are not likely to yield the same returns in the form of external R & D support. After all, competition for external resources creates an environment in which some institutions are positioned to win while others are not, leading to widening inequities in resources across institutions (Cantwell & Taylor, 2015; Slaughter & Rhoades, 2004). In other words, PBF systems with research incentives offer a potential mechanism through which institutions with greater resources and prestige, which often go hand in hand, are able to have built-in advantages to pursue prestige-seeking behaviors such that their relative advantage begets further advantages (Taylor & Cantwell, 2019). Under this scenario, PBF systems with research incentives as part of their PBF formula may widen existing funding disparities between higher education institutions, leading to yet another potential unintended consequence of PBF policies.

PBF systems with research incentives that institutions can opt into could serve to level the playing field for colleges and universities to be able to compete for both state funds and external research funds if lowerresourced institutions are able to reallocate resources toward prioritizing R & D activity. Since we did not find differential impacts on institutional research expenditures or state appropriations by MSI status, it is possible that any institution that is able to reallocate funds toward research activities may see gains in state funding under such a policy. If so, PBF systems with research incentives that institutions can opt into could serve as one way to build research capacity of institutions within a state and thereby better position any institution to compete for both state and federal dollars.

However, findings from our study also highlight the limitations of PBF research incentives as an effective strategy for aligning institutional behavior with state workforce and economic development goals. Absent a PBF policy that allows institutions to select the metrics on which they are evaluated, we found no evidence of an impact of PBF research incentives on institutional research expenditures or state appropriations. PBF research incentives without the “choose your own adventure” option may not be an effective lever when it comes to leveraging state and institutional resources to compete for and secure external R & D funds. The limits of PBF in altering institutional behavior to improve research activities are hardly surprising given decades of empirical work demonstrating the limits of PBF policies in the higher education sector when it comes to other incentivized metrics, such as retention or graduation (Ortagus et al., 2020).

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Figure 1. PBF Research Incentives in Place by State for Eligible Institutions

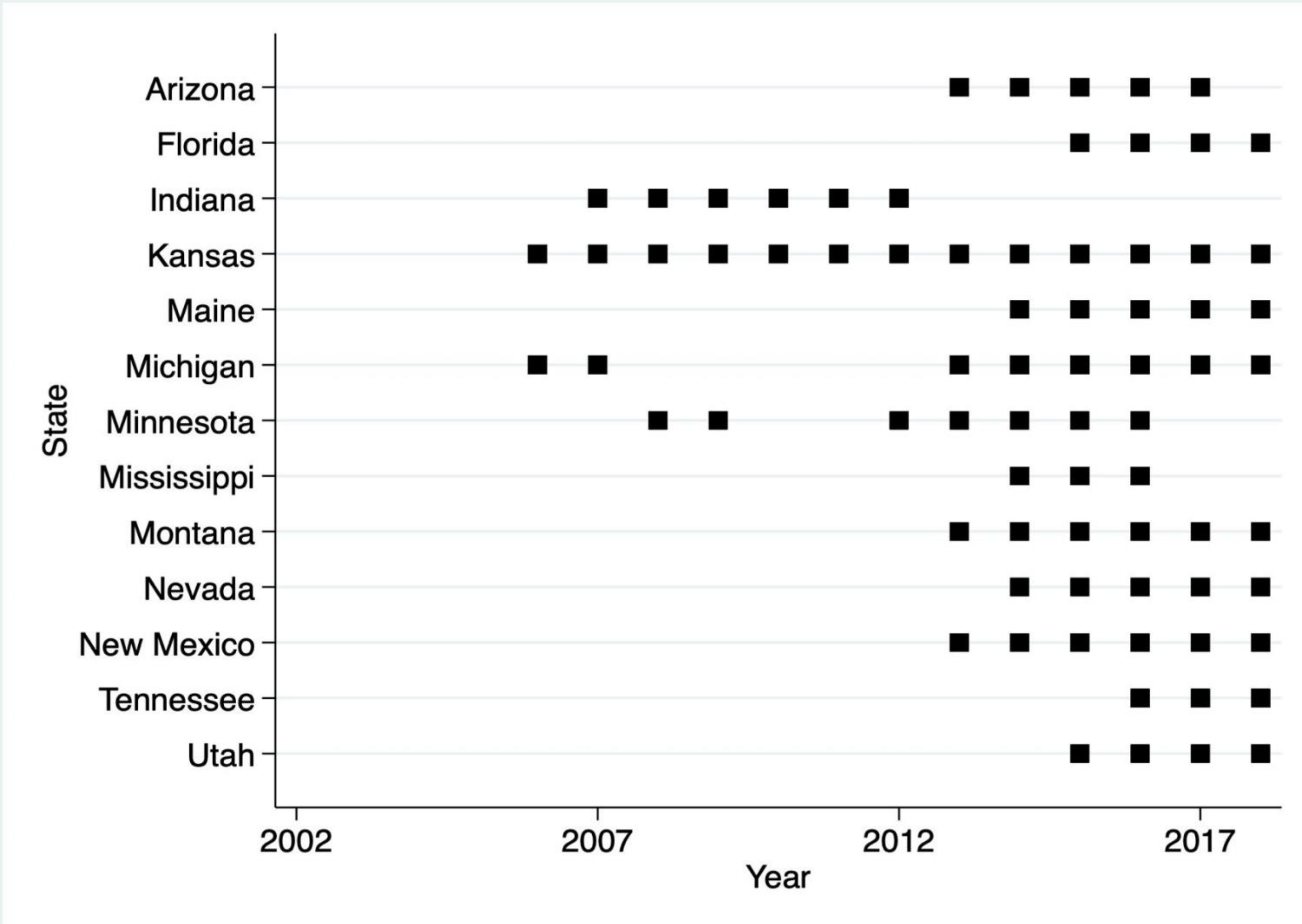


Figure 2. Estimated propensity scores Pre- and Post-weighting

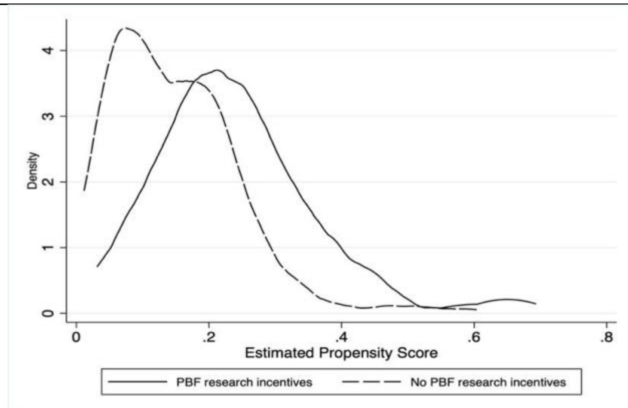
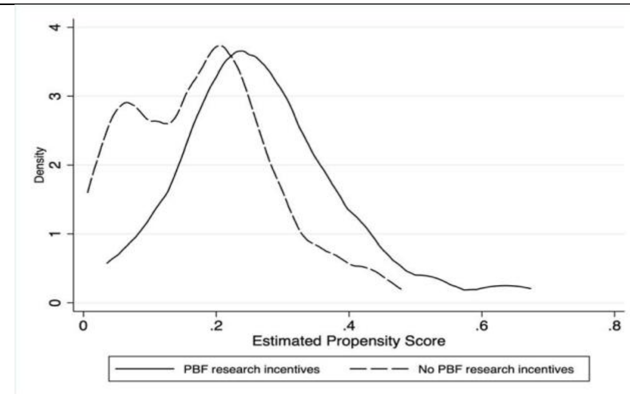
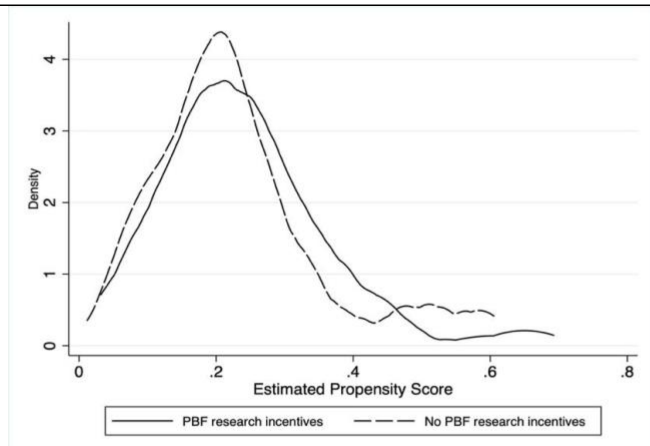
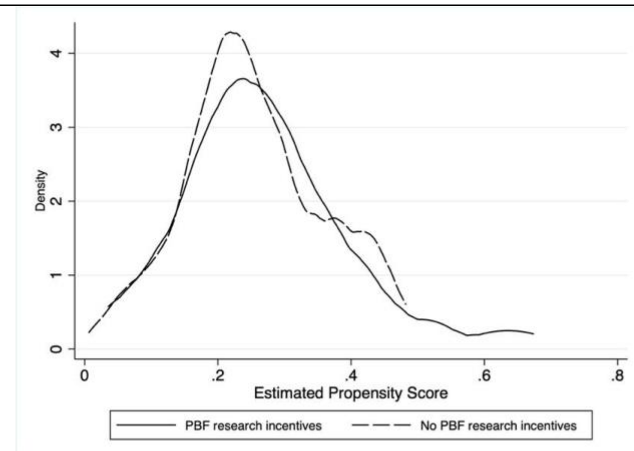
	Full Sample	Non-Minority Serving Institutions
Pre-weighting		
Post-weighting		

Table 1. Descriptive summary of the variables

			Treated	Neighboring Group	National Group	IPSW Treated	IPSW Comparison
State-Level Covariates	State control						
		Republican	47.43%	40.48%	29.55%	47.34%	33.50%
		Democratic	6.54%	20.88%	24.38%	6.64%	22.04%
		divided/others	46.03%	38.64%	46.08%	46.02%	44.46%
	Percentage of state annual appropriation to HE		0.103	0.128	0.114	0.104	0.113
			(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
	PBF in Place		56.49%	26.40%	24.64%	56.64%	25.67%
Institution-Level Covariates	Institutional size						
		under 1,000	0.00%	0.00%	0.08%	0.00%	0.00%
		1,000–4,999	3.83%	13.17%	13.50%	3.89%	4.74%
		5,000–9,999	25.21%	24.96%	29.10%	25.62%	24.42%
		10,000–19,999	30.91%	28.34%	29.06%	31.40%	32.70%
		above 20,000	40.06%	33.53%	28.26%	39.09%	38.14%
	Location						
		city	62.00%	56.68%	51.17%	61.39%	58.29%
		suburb	11.20%	13.80%	19.99%	11.39%	14.55%
		town	22.50%	25.67%	25.19%	22.87%	24.11%
		rural	4.30%	3.84%	3.65%	4.36%	3.05%

Institution has hospital	6.07%	8.35%	7.96%	4.55%	9.17%
Institution grants a medical degree	28.85%	17.67%	16.30%	27.70%	25.07%
Minority-serving institution (MSI)	15.87%	33.53%	31.25%	16.13%	15.88%
Percentage of applicants admitted	0.758	0.715	0.690	0.763	0.715
	(0.005)	(0.003)	(0.003)	(0.004)	(0.003)
Tuition and fee revenue per FTE	9640.52	8583.54	8724.30	9263.22	9893.70
	(151.56)	(76.79)	(64.28)	(122.41)	(141.95)
Federal contract and grant revenue per FTE	5454.95	3971.87	3724.75	5006.00	5108.74
	(259.49)	(106.07)	(83.48)	(239.71)	(212.18)
State contract and grant revenue per FTE	703.31	815.77	976.46	707.58	830.64
	(28.14)	(19.82)	(19.47)	(28.55)	(16.42)
Local/private contract and grant revenue per FTE	1831.85	978.00	1037.60	1757.14	1340.95
	(103.02)	(32.89)	(38.85)	(103.05)	(47.38)
State appropriations per FTE	8652.07	9091.20	9602.73	9581.57	9120.82
	(170.18)	(86.37)	(117.88)	(171.59)	(145.21)
Instructional cost per FTE	10492.35	9933.08	10167.23	10138.64	10533.54
	(168.05)	(108.76)	(104.59)	(145.28)	(137.71)
Number of Institutions	63	206	306	62	310
Number of Observations	1,057	3,445	4,971	1,040	5,186

Note. Standard error in parenthesis.

Table 2: Standardized differences of the unweighted and weighted sample

	Full Sample		NMSI Sample	
Variable	*Pre-weighting*	*Post-weighting*	*Pre-weighting*	*Post-weighting*
Institutional size	0.342	0.006	0.325	0.033
Location	-0.047	0.011	-0.035	0.073
Institution has hospital	-0.035	-0.094	-0.057	0.033
Institution grants a medical degree	-0.202	0.023	-0.040	0.012
Minority-serving institution (MSI)	-0.354	0.007	-	
Percentage of applicants admitted	0.073	-0.072	0.020	-0.075
Tuition and fee revenue per FTE	0.324	-0.077	0.192	0.041
Federal contract and grant revenue per FTE	0.321	0.005	0.103	0.028
State contract and grant revenue per FTE	-0.069	0.053	-0.176	-0.024
Local/private contract & grant revenue per FTE	0.398	0.131	0.192	-0.017
State appropriations per FTE	0.147	0.121	0.014	0.020
Instructional cost per FTE	0.291	0.088	0.130	0.006

Table 3. Imbalance measurement of the Continuous Variables before and after CEM procedure for MSIs

	Variable	L1	Mean	Min	25%	50%	75%	Max
Pre-CEM	medical degree granting	0.25	-0.25	0.00	-1.00	0.00	0.00	0.00
	federal contract and grant revenue per FTE	0.76	8975.80	2053.80	7008.40	9028.10	9893.60	19062.00
	local/private contract and grant revenue per FTE	0.33	1964.80	194.50	273.50	561.18	2480.10	4888.80
	state appropriations per FTE	0.39	3904.20	1903.50	788.34	-137.75	8353.60	-27199.00
	instructional cost per FTE	0.29	2423.10	1472.20	596.16	2036.00	4889.40	-14307.00
Post-CEM	medical degree granting	0.00	-0.02	0.00	0.00	0.00	0.00	0.00
	federal contract and grant revenue per FTE	0.23	7803.90	1921.20	135.15	7164.10	7490.80	21845.00
	local/private contract and grant revenue per FTE	0.25	1804.50	17.14	-2.15	1466.70	955.54	4888.80
	state appropriations per FTE	0.29	4205.50	2528.40	313.32	5869.60	6214.00	655.05
	instructional cost per FTE	0.02	1102.90	12.30	-47.68	2509.50	695.25	-3882.20

Table 4. Descriptive summary of dependent variable

	Treated	Neighboring Group	National Group	IPSW Treated	IPSW Comparison
Total amount of research expenditure (in $1,000)	104,621	73,642	64,383	93,341	94,207
	(5,310)	(2,701)	(2,090)	(4,617)	(3,332)
Relative share of research expenditure	0.107	0.068	0.065	0.106	0.084
	(0.003)	(0.001)	(0.001)	(0.003)	(0.002)
Total amount of state appropriations (in $1,000)	145,725	115,014	108,895	142,161	125,515
	(4,555)	(2,057)	(1,687)	(4,540)	(2,402)

Note. IPSW = Inverse Propensity Score Weighting. FTE = full-time equivalent. Standard error in parenthesis.

Table 5. Coefficients of PBF research incentives on research expenditure

	No Lag			One-year Lag			Two-year Lag		
Variable	**Neighboring Group**	**National Group**	**IPSW/CEM Group**	**Neighboring Group**	**National Group**	**IPSW/CEM Group**	**Neighboring Group**	**National Group**	**IPSW/CEM Group**
Panel A: Full Sample									
Total amount of research expenditure (logged)	0.002	0.007	0.006	0.044	0.039	0.047	0.058	0.048	0.058
	(0.038)	(0.038)	(0.037)	(0.029)	(0.029)	(0.028)	(0.034)	(0.035)	(0.036)
Relative share of research expenditure	-0.004	-0.003	-0.002	-0.002	0.039	-0.001	-0.001	-0.001	-0.001
	(0.002)	(0.003)	(0.002)	(0.002)	(0.029)	(0.002)	(0.002)	(0.002)	(0.002)
Panel B: MSI Sub-sample									
Total amount of research expenditure (logged)	-0.023	0.011	0.221	0.069	0.067	0.056	0.164	0.126	-0.082
	(0.069)	(0.092)	(0.383)	(0.048)	(0.053)	(0.173)	(0.106)	(0.108)	(0.271)
Relative share of research expenditure	-0.013	-0.013	-0.010	-0.013	-0.014	-0.011	-0.018	-0.019	-0.018
	(0.011)	(0.012)	(0.012)	(0.010)	(0.011)	(0.012)	(0.011)	(0.011)	(0.013)
Panel C: NMSI Sub-sample									
	0.002	0.008	0.010	0.040	0.043	0.050	0.041	0.045	0.044

Total amount of research expenditure (logged)	(0.042)	(0.042)	(0.042)	(0.033)	(0.032)	(0.033)	(0.034)	(0.035)	(0.034)
Relative share of research expenditure	-0.002	-0.001	-0.001	0.000	0.001	0.000	0.002	0.002	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)

Note. Standard error in parenthesis. All model specifications controlled for institution and year fixed effects, and included institution-specific linear time trends.

Table 6. Coefficients of PBF research incentives (funded) on research expenditure

Variable	No Lag			One-year Lag			Two-year Lag		
	Neighboring Group	**National Group**	**IPSW/CEM Group**	**Neighboring Group**	**National Group**	**PSW/CEM Group**	**Neighboring Group**	**National Group**	**IPSW/CEM Group**
Panel D: Full Sample									
Total amount of research expenditure (logged)	-0.006	-0.001	-0.003	0.045	0.042	0.048	0.038	0.029	0.041
	(0.035)	(0.035)	(0.034)	(0.031)	(0.031)	(0.030)	(0.033)	(0.033)	(0.035)
Relative share of research expenditure	-0.003	-0.002	-0.002	-0.001	-0.001	0.000	0.000	0.000	0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Panel E: MSI Sub-sample									
Total amount of research expenditure (logged)	-0.013	0.015	0.183	0.071	0.073	0.114	0.170	0.142	0.013
	(0.070)	(0.092)	(0.347)	(0.040)	(0.051)	(0.206)	(0.098)	(0.099)	(0.204)
Relative share of research expenditure	-0.009	-0.010	-0.006	-0.010	-0.011	-0.008	-0.015	-0.016	-0.016
	(0.010)	(0.011)	(0.012)	(0.009)	(0.010)	(0.011)	(0.010)	(0.011)	(0.012)
Panel F: NMSI Sub-sample									
	-0.010	-0.002	-0.002	0.039	0.043	0.049	0.023	0.024	0.026

Total amount of research expenditure (logged)	(0.038)	(0.038)	(0.038)	(0.035)	(0.034)	(0.034)	(0.032)	(0.033)	(0.033)
Relative share of research expenditure	-0.002	-0.001	-0.001	0.000	0.001	0.000	0.001	0.002	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)

Note. Standard error in parenthesis. All model specifications controlled for institution and year fixed effects, and included institution-specific linear time trends.

Table 7. Coefficients of PBF research incentives on state appropriations

	No Lag			One-year Lag			Two-year Lag		
Treatment	**Neighboring Group**	**National Group**	**IPSW/CEM Group**	**Neighboring Group**	**National Group**	**IPSW/CEM Group**	**Neighboring Group**	**National Group**	**IPSW/CEM Group**
Panel G: Full Sample									
PBF research incentives	0.017	-0.002	-0.002	0.042	0.033	0.009	0.083	0.075*	0.034
	(0.030)	(0.025)	(0.023)	(0.041)	(0.034)	(0.029)	(0.043)	(0.038)	(0.030)
PBF research incentives (funded)	0.006	-0.007	-0.008	0.026	0.020	0.001	0.058	0.054	0.021
	(0.022)	(0.018)	(0.015)	(0.029)	(0.025)	(0.018)	(0.031)	(0.028)	(0.019)
Panel H: MSI Sub-sample									
PBF research incentives	-0.047	-0.050	0.024	-0.008	-0.010	0.017	0.019	0.016	0.010
	(0.043)	(0.036)	(0.055)	(0.049)	(0.041)	(0.085)	(0.060)	(0.055)	(0.092)
PBF research incentives (funded)	-0.043	-0.046	0.009	0.000	0.001	0.026	0.032	0.030	0.034
	(0.038)	(0.033)	(0.038)	(0.041)	(0.036)	(0.050)	(0.049)	(0.046)	(0.063)
Panel I: NMSI Sample									
PBF research incentives	0.043	0.010	0.012	0.057	0.045	0.029	0.080	0.082	0.057*
	(0.041)	(0.030)	(0.021)	(0.059)	(0.043)	(0.026)	(0.064)	(0.048)	(0.028)
PBF research incentives (funded)	0.022	0.001	0.000	0.033	0.025	0.010	0.049	0.053	0.031
	(0.029)	(0.022)	(0.014)	(0.040)	(0.031)	(0.017)	(0.042)	(0.034)	(0.018)

Note. Standard error in parenthesis. All model specifications controlled for general PBF policy in place/funded, institution and year fixed effects, and included institution-specific linear time trends. * $p < .05$

Table 8. Coefficients of PBF research incentive types on research expenditure and state appropriations

		No Lag			One-year Lag			Two-year Lag		
Variable		**Neighboring Group**	**National Group**	**CEM Group**	**Neighboring Group**	**National Group**	**CEM Group**	**Neighboring Group**	**National Group**	**CEM Group**
Total amount of research expenditure (logged)	Mandatory	-0.007	-0.002	0.012	0.041	0.034	0.045	0.067	0.053	0.060
		(0.044)	(0.044)	(0.050)	(0.033)	(0.032)	(0.036)	(0.039)	(0.040)	(0.042)
	Self-selected	0.031	0.036	0.086	0.053	0.055	0.067	0.015	0.022	0.004
		(0.068)	(0.068)	(0.076)	(0.062)	(0.062)	(0.067)	(0.055)	(0.054)	(0.067)
Relative share of research expenditure	Mandatory	-0.006*	-0.006	-0.006*	-0.004	-0.004	-0.004	-0.002	-0.002	-0.002
		(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
	Self-selected	0.007*	0.007*	0.006	0.007*	0.008*	0.008*	0.006	0.007	0.006
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)	(0.004)
Total amount of state appropriations (logged)	Mandatory	-0.003	-0.022	-0.023	0.009	0.001	-0.019	0.066	0.059	0.022
		(0.034)	(0.028)	(0.042)	(0.045)	(0.039)	(0.053)	(0.046)	(0.042)	(0.053)
	Self-selected	0.068*	0.049	0.061*	0.074	0.075*	0.058	0.076	0.081*	0.069
		(0.029)	(0.027)	(0.030)	(0.039)	(0.036)	(0.035)	(0.042)	(0.038)	(0.038)

Note. Standard error in parenthesis. All model specifications controlled for institution and year fixed effects, and included institution-specific linear time trends. * $p < .05$,

Appendix A. Institutions with PBF policies with research metrics between 2002 and 2018

State	Institution	Treated Years	Treated Years (funded)
AZ	Arizona State University	2013-2017	2013-2014, 2016-2017
	University of Arizona	2013-2017	2013-2014, 2016-2017
	Northern Arizona University	2013-2017	2013-2014, 2016-2017
FL	Florida Agricultural and Mechanical University	2015-2020	2015-2020
	University of Florida	2015-2020	2015-2020
IN	Ball State University	2004-2012	2004-2012
	Indiana University-Purdue University-Fort Wayne	2004-2012	2004-2012
	Indiana University-Purdue University-Indianapolis	2004-2012	2004-2012
	University of Southern Indiana	2004-2012	2004-2012
	Indiana State University	2004-2012	2004-2012
	Indiana University-South Bend	2004-2012	2004-2012
	Indiana University-Bloomington	2004-2012	2004-2012
	Indiana University-Northwest	2004-2012	2004-2012
	Indiana University-Southeast	2004-2012	2004-2012
	Purdue University-Main Campus	2004-2012	2004-2012
KS	Emporia State University	2006-2020	2006-2009, 2013, 2015, 2019-2020
	Fort Hays State University	2006-2020	2006-2009, 2013, 2015, 2019-2020
	University of Kansas	2006-2020	2006-2009, 2013, 2015, 2019-2020
	Kansas State University	2006-2020	2006-2009, 2013, 2015, 2019-2020

	Pittsburg State University	2006-2020	2006-2009, 2013, 2015, 2019-2020
	Washburn University	2006-2020	2006-2009, 2013, 2015, 2019-2020
	Wichita State University	2006-2020	2006-2009, 2013, 2015, 2019-2020
ME	University of Maine	2014-2018	2014-2018
	University of Southern Maine	2014-2018	2014-2018
MI	Central Michigan University	2006-2007, 2013-2020	2006-2007, 2013-2020
	Eastern Michigan University	2006-2007, 2013-2020	2006-2007, 2013-2020
	Ferris State University	2006-2007, 2013-2020	2006-2007, 2013-2020
	Grand Valley State University	2006-2007, 2013-2020	2006-2007, 2013-2020
	Lake Superior State University	2006-2007, 2013-2020	2006-2007, 2013-2020
	University of Michigan-Ann Arbor	2006-2007, 2013-2020	2006-2007, 2013-2020
	Michigan State University	2006-2007, 2013-2020	2006-2007, 2013-2020
	Michigan Technological University	2006-2007, 2013-2020	2006-2007, 2013-2020
	University of Michigan-Dearborn	2006-2007, 2013-2020	2006-2007, 2013-2020
	University of Michigan-Flint	2006-2007, 2013-2020	2006-2007, 2013-2020

	Northern Michigan University	2006-2007, 2013-2020	2006-2007, 2013-2020
	Oakland University	2006-2007, 2013-2020	2006-2007, 2013-2020
	Saginaw Valley State University	2006-2007, 2013-2020	2006-2007, 2013-2020
	Wayne State University	2006-2007, 2013-2020	2006-2007, 2013-2020
	Western Michigan University	2006-2007, 2013-2020	2006-2007, 2013-2020
MN	University of Minnesota-Twin Cities	2008-2009, 2012-2016	2008-2009, 2012-2016
	University of Minnesota-Duluth	2008-2009, 2012-2016	2008-2009, 2012-2016
MS	Jackson State University	2014-2016	2014
	University of Mississippi	2014-2016	2014
	Mississippi State University	2014-2016	2014
	University of Southern Mississippi	2014-2016	2014
MT	Montana State University	2013-2020	2015-2020
	The University of Montana	2013-2020	2015-2020
NV	University of Nevada-Las Vegas	2014-2020	2015-2020
	University of Nevada-Reno	2014-2020	2015-2020
NM	New Mexico Institute of Mining and Technology	2013-2020	2013-2020
	University of New Mexico-Main Campus	2013-2020	2013-2020

	New Mexico State University-Main Campus	2013-2020	2013-2020
TN	Austin Peay State University	2016-2020	2016-2020
	East Tennessee State University	2016-2020	2016-2020
	University of Memphis	2016-2020	2016-2020
	Middle Tennessee State University	2016-2020	2016-2020
	The University of Tennessee at Chattanooga	2016-2020	2016-2020
	The University of Tennessee	2016-2020	2016-2020
	The University of Tennessee-Martin	2016-2020	2016-2020
	Tennessee State University	2016-2020	2016-2020
	Tennessee Technological University	2016-2020	2016-2020
UT	Utah State University	2015-2020	2015-2020
	University of Utah	2015-2020	2015-2020

Note. Each year represent fiscal year. For example, 2019-2020 represents 2018-19 and 2019-20 fiscal years.

Appendix B. Control Variables and Sources in Outcome Models

	Variables	Source	Variable Characteristics
Outcome Variable	Amount of research expenditure (logged)	IPEDS	Continuous
	Share of research expenditures relative to total expenditures	IPEDS	Continuous
	Amount of state appropriations (logged)	IPEDS	Continuous
Treatment Variable	PBF research incentives	budget and policy documents at state and institutional level	0 = no PBF research incentives; 1 = PBF research incentives
	PBF research incentives with actual funding		0 = no PBF research incentives; 1 = PBF research incentives with actual funding
	PBF with research metrics as an option		0 = no PBF research incentives; 1 = mandatory PBF research incentives; 2 = self-select PBF research incentives
State-Level Covariates	State control	CSG	0 = Republican; 1 = Democratic; 2 = divided/others
	PBF Policy in place[1]	budget and policy documents at state and institutional level	0 = no PBF; 1 = PBF in place
	Percentage of state appropriation to HE	NASBO	Continuous
Institution -Level Covariates	Institutional size	IPEDS	1 = under 1,000; 2 = 1,000–4,999; 3 = 5,000–9,999; 4 = 10,000–19,999; 5 = above 20,000
	Location	IPEDS	1 = city; 2 = suburb; 3 = town; 4 = rural
	Whether institution has hospital	IPEDS	0 = no; 1 = yes
	Whether institution grants a medical degree	IPEDS	0 = no; 1 = yes

	Minority-serving institution (MSI) status	ED	0 = no; 1 = yes
	Percentage of applicants admitted	IPEDS	Continuous
	Tuition and fee revenue per FTE	IPEDS	Continuous
	Federal contract and grant revenue per FTE	IPEDS	Continuous
	State contract and grant revenue per FTE	IPEDS	Continuous
	Local/private contract and grant revenue per FTE	IPEDS	Continuous
	Instructional cost per FTE	IPEDS	Continuous
	State appropriations per FTE[2]	IPEDS	Continuous

Note. IPEDS = The Integrated Postsecondary Education Data System. CSG = The Council of State Governments. NASBO = National Association of State Budget Officers. ED = U.S. Department of Education. PBF = Performance-based funding.
1 = only included in model specifications for the amount of state appropriations (logged)
2 = only included in model specifications for the amount of research expenditure (logged) and the share of research expenditures relative to total expenditures