

Windfall Revenue and Agricultural Land Use: Evidence from Brazil’s FPM Transfer Formula*

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Abstract

Brazil’s Fundo de Participação dos Municípios (FPM) distributes federal revenue to municipalities via a statutory coefficient schedule with 17 population thresholds. Crossing a threshold raises annual transfers by roughly R\$0.8 million. Using municipal crop-area data for 5,500 municipalities (IBGE PAM, 2000–2019), I find an insignificant full-sample cross-sectional RDD estimate (-0.22 log points) alongside a larger positive gap for Amazon-biome municipalities. A pre-period placebo reveals that comparable crop-area differences predate the thresholds, precluding causal interpretation of the cross-section. A panel difference-in-differences exploiting bracket changes between censuses yields a marginally significant intensive-margin effect of 2.9% per bracket crossed ($p = 0.064$). The evidence is suggestive that FPM windfalls raise agricultural area in frontier municipalities, but sorting at thresholds limits stronger causal claims.

JEL Codes: H77, Q15, Q18, O13, R11

Keywords: fiscal federalism, intergovernmental transfers, agricultural land use, regression discontinuity, Brazil

1 Introduction

In a typical year, a municipality of 10,200 residents in the Brazilian Amazon receives roughly R\$200,000 more in federal transfers than a municipality of 10,100 residents—not because

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it is larger, more productive, or better governed, but because it sits just above a statutory population threshold in the FPM coefficient schedule. This paper asks whether those extra funds matter for agricultural land use—and what that implies for how municipalities use discretionary revenue.

The Fundo de Participação dos Municípios is the most important source of revenue for most Brazilian municipalities. Established by Decree-Law 1,881/1981 and codified in LC 91/1997, the FPM distributes 22.5% of federal income and industrial product taxes to all municipalities in Brazil’s interior according to a formula based solely on population. A statutory coefficient schedule assigns each municipality to one of 18 brackets; each bracket transition raises the coefficient by 0.2. The result is a step-function relationship between population and transfers, with 17 discrete thresholds—ranging from 10,189 to 156,217 residents—that create quasi-random variation in municipal revenue.

This design has attracted substantial econometric attention. [Litschig and Morrison \(2013\)](#) exploit the same thresholds to show that FPM transfers increase local public spending and educational attainment. [Gadenne \(2017\)](#) examines how Brazilian municipalities spend windfall revenues, finding higher public-good provision. [Brollo et al. \(2013\)](#) document political economy effects. What remains unknown is whether these fiscal windfalls translate into changes in land use—particularly agricultural expansion.

The question is economically and ecologically significant. Brazil has experienced dramatic agricultural expansion since the 1990s, driven partly by the *cerrado* and Amazon frontiers where municipal governments play a central role in infrastructure provision ([Assunção et al., 2015](#)). If fiscal transfers fund road construction, agricultural credit, or technical assistance, they may lower the cost of forest conversion. Conversely, if transfers fund social services, they may urbanize frontier populations and reduce agricultural pressure. The direction is theoretically ambiguous, and the magnitude is unknown.

I address this question using a multi-cutoff RDD that exploits all 17 FPM population thresholds simultaneously. My outcome is the average annual area of crops planted (in hectares) from the IBGE Pesquisa Agrícola Municipal (PAM), averaged over 2005–2015. The running variable is each municipality’s 2000 census population, normalized relative to each threshold. The stacked multi-cutoff estimator of [Cattaneo et al. \(2021\)](#) allows me to pool across thresholds while controlling for threshold-specific fixed effects, substantially increasing precision relative to single-threshold designs.

Three patterns emerge. First, the full-sample cross-sectional RDD estimate is negative and statistically insignificant (-0.22 log points, $p = 0.13$). Second, there is heterogeneity by biome: Amazon-biome municipalities above thresholds show substantially larger crop areas than those below ($+0.85$ log points), while non-Amazon municipalities show a small negative

gap. But a pre-period placebo test reveals that these gaps existed *before* FPM thresholds became binding revenue determinants, indicating baseline sorting at the cutoffs that precludes causal interpretation. Third, a within-municipality panel DiD comparing municipalities that crossed FPM brackets between censuses against stable stayers yields a marginally significant intensive-margin effect of 2.9% per bracket crossed ($p = 0.064$), which survives municipality and year fixed effects.

The panel DiD estimate—though imprecise—is the paper’s most causally credible result. It is consistent with the mechanism that fiscal windfalls in frontier municipalities fund the infrastructure that enables agricultural conversion, while the FPM cross-sectional differences may partly reflect pre-existing selection of agricultural municipalities into higher population brackets.

I should note two important limitations at the outset. The outcome variable—municipal annual crop area from IBGE PAM—captures a flow of agricultural input use rather than land conversion per se. Changes in PAM crop area can arise through intensification (more area on existing farmland) or extensification (clearing new land), and distinguishing these requires satellite land-cover data that were not available for this analysis. Second, the cross-sectional RDD has an inherent validity concern from pre-existing baseline differences at FPM thresholds. The paper is therefore better read as evidence on fiscal transfers and agricultural production structure than as a clean causal estimate of environmental costs of decentralization.

The remainder of the paper proceeds as follows. Section 2 describes the FPM institutional context and data. Section 3 presents the identification strategies. Section 4 reports results and robustness checks. Section 5 discusses implications and concludes.

2 Institutional Context and Data

The FPM Transfer System. The FPM is Brazil’s primary mechanism for horizontal fiscal equalization. Its interior fund (FPM Interior) distributes funds to all municipalities with populations under 156,216 residents—about 95% of Brazilian municipalities. The allocation formula has two components: a population bracket coefficient and a per-capita income adjustment. The population coefficient dominates for most municipalities.

The 17 population thresholds range from 10,189 to 156,217 residents and are defined in statutory law. Each crossing raises the coefficient by 0.2: municipalities in bracket 1 (population below 10,188) receive a coefficient of 0.6, while municipalities in bracket 18 (population above 156,216) receive 4.0. The total FPM Interior pool in 2005 was approximately R\$22 billion; a coefficient increment of 0.2 translates to approximately R\$0.8 million in

additional annual transfers for a typical municipality—roughly 20% of the median municipal revenue.

Crucially, the FPM coefficient is determined exclusively by population census counts, not by current-year estimates. This means the population is fixed at census year values (2000 or 2010) for the intervening decade. During 2000–2009, coefficients are based on the 2000 census; during 2010–2019, on the 2010 census. This institutional feature creates a clean regression discontinuity: municipalities on either side of a threshold are similar in all unobserved characteristics but differ discretely in annual transfer receipts.

Data Sources. Population. I obtain 2000 and 2010 census municipal population from IBGE SIDRA (table 200, variable 93), accessed via the public API. The full dataset contains 5,507 municipalities in 2000 and 5,565 in 2010, covering all 26 states and the Federal District.

Agricultural area. I use the IBGE Pesquisa Agrícola Municipal (PAM), SIDRA table 1612, variable 109 (area planted, annual crops, in hectares), available annually from 1988 through 2019. PAM covers all permanent and annual crops by municipality and provides the longest consistent municipal-level agricultural series for Brazil. I focus on annual crops (temporary crops including soybeans, corn, cotton, and sugarcane) as these are most responsive to short-run infrastructure and credit conditions. The full dataset contains 109,493 municipality-year observations over 2000–2019.

Analytic datasets. I construct three analytic datasets. The cross-sectional RDD dataset averages log crop area over 2005–2015 for each municipality, yielding 4,804 observations with non-zero crop area. The stacked multi-cutoff dataset generates one observation per municipality-threshold pair within a 30% bandwidth of each threshold, yielding 8,194 observations across all 17 thresholds. The panel dataset contains 109,493 municipality-year observations over 2000–2019.

3 Empirical Strategy

Multi-Cutoff RDD Design. I implement the stacked multi-cutoff RDD of [Cattaneo et al. \(2021\)](#). For each threshold $k = 1, \dots, 17$ with cutoff c_k , I define the normalized running variable for municipality i as

$$x_{ik} = \frac{\text{pop}_i - c_k}{c_k},$$

where pop_i is the 2000 census population. The treatment indicator is $D_{ik} = \mathbf{1}[\text{pop}_i \geq c_k]$. I restrict the sample to municipality-threshold pairs within a bandwidth h of each cutoff.

The main estimating equation is:

$$\bar{y}_i = \alpha + \tau D_{ik} + \beta_0 x_{ik} \cdot (1 - D_{ik}) + \beta_1 x_{ik} \cdot D_{ik} + \mu_k + \varepsilon_{ik},$$

where \bar{y}_i is average log crop area 2005–2015, μ_k are threshold fixed effects, and triangular kernel weights $w_{ik} = 1 - |x_{ik}|/h$ downweight observations further from the cutoff. I cluster standard errors by municipality.

I select the bandwidth using the MSE-optimal data-driven procedure of [Calonico et al. \(2014\)](#), implemented via `rdrobust`. Applied to the stacked dataset, this yields $h^* = 11.7\%$ of each threshold, which I use as my primary bandwidth. I verify robustness to bandwidths ranging from 10% to 30%.

A key validity condition is that municipalities cannot manipulate their population to sort above thresholds. I test this using the [Cattaneo et al. \(2018\)](#) density test implemented via `rddensity`. Only 3 of the 17 thresholds show statistically significant density discontinuities at the $p < 0.05$ level (thresholds 1, 3, and 17), and the pooled test rejects but is driven by these three. I also report a pre-period placebo test (crop area 2000–2004 as the outcome), which reveals baseline sorting that limits causal interpretation of the cross-sectional design.

Panel Difference-in-Differences. To address pre-existing selection at thresholds, I complement the cross-sectional RDD with a panel difference-in-differences that exploits *changes* in FPM bracket between the 2000 and 2010 censuses. Of the 5,507 municipalities in my sample, 1,357 moved to a higher FPM bracket between censuses (“crossers”) and 4,015 remained in the same bracket (“stayers”).

The DiD estimating equation is:

$$y_{it} = \alpha_i + \gamma_t + \delta \cdot \text{Crossed}_i \times \text{Post}_{2010,t} + \varepsilon_{it},$$

where α_i are municipality fixed effects, γ_t are year fixed effects, and $\text{Crossed}_i = 1$ if municipality i moved to a higher bracket. I also estimate the intensive-margin specification, replacing Crossed_i with the number of brackets crossed. This within-municipality design differences out time-invariant characteristics correlated with threshold crossing, including pre-existing agricultural endowments.

4 Results

Sample and Summary Statistics. Table 1 presents summary statistics for the RDD sample. Within the MSE-optimal bandwidth of 11.7%, the stacked dataset contains 3,018

municipality-threshold observations across 2,579 unique municipalities. Municipalities above FPM thresholds have slightly larger populations (mean 26,200 vs. 21,300 thousand) and higher average crop area (16,400 vs. 14,800 hectares), consistent with the pre-existing sorting documented by the placebo test.

Main RDD Results. Table 2 presents the multi-cutoff RDD estimates. The full-sample estimate is -0.224 log points ($SE = 0.147$, $p = 0.127$), statistically insignificant and suggesting at most a modest negative effect of FPM transfers on aggregate crop area.

There is heterogeneity by biome, though it must be interpreted cautiously. In Amazon-biome municipalities (states AC, AM, AP, PA, RO, RR, TO), the cross-sectional gap at FPM thresholds is large ($+0.853$ log points, $SE = 0.353$, $p = 0.015$), implying 135% higher crop area just above relative to just below the cutoff. Non-Amazon municipalities show a small negative gap (-0.291 , $SE = 0.156$, $p = 0.062$). The Amazon subsample contains only 274 municipality-threshold observations, so this estimate is imprecise and sensitive to specification.

Critically, the pre-period placebo test (Column 3 of Table 5) yields an estimate of -0.226 log points ($SE = 0.134$) using 2000–2004 crop area as the outcome. This is statistically and economically comparable to the main estimate, indicating that municipalities above FPM thresholds had larger crop areas *before* the thresholds determined their transfer coefficients. This is strong evidence of pre-existing selection: municipalities that grow to cross population thresholds may systematically be those with favorable agricultural conditions. The cross-sectional estimates—including the Amazon heterogeneity—therefore cannot be given a clean causal interpretation. They describe a correlation between FPM bracket assignment and crop area that predates the FPM transfers themselves.

Panel DiD: Threshold Crossers vs. Stayers. Table 3 presents the panel DiD estimates. Column (1) shows the binary treatment effect: municipalities that crossed to a higher FPM bracket between the 2000 and 2010 censuses experienced a 3.0% higher growth in annual crop area relative to stayers ($\hat{\delta} = 0.030$, $SE = 0.022$, $p = 0.169$). While this point estimate is positive and economically meaningful, it is not significant at conventional levels.

The intensive-margin specification (Column 2) is more informative. Each additional FPM bracket crossed between censuses is associated with a 2.9% increase in annual crop area ($\hat{\delta} = 0.029$, $SE = 0.016$, $p = 0.064$). The higher precision and marginal significance of the intensive-margin estimate reflects the additional identifying variation from municipalities that crossed multiple brackets. Column (3) restricts to Amazon-biome municipalities and yields a positive but imprecise estimate, consistent with the cross-sectional heterogeneity.

The panel DiD removes time-invariant differences in agricultural potential, soil quality, and infrastructure. However, a residual concern is that population growth between 2000 and 2010—which triggers bracket changes—may itself be correlated with agricultural development trends. An ideal validation would include event-study plots showing parallel pre-trends between crossers and stayers, which this analysis cannot provide without panel-quality figures. The panel estimate should therefore be interpreted as suggestive rather than definitive: it is consistent with a causal effect of transfers on crop area, but alternative channels (common growth shocks, frontier expansion dynamics) cannot be fully ruled out.

Robustness. Table 4 examines bandwidth robustness. Across bandwidths from 10% to 30%, the full-sample cross-sectional estimate ranges from -0.12 to -0.23 and is consistently negative, ruling out large positive aggregate effects. The leave-one-threshold-out sensitivity analysis shows that the cross-sectional estimate is stable to dropping any single threshold, with the range $[-0.32, -0.14]$.

Table 5 shows that the donut-hole robustness check (excluding pairs within 1% of each cutoff) yields a larger negative estimate (-0.354 , $SE = 0.184$), suggesting that municipalities extremely close to thresholds do not drive the result. The panel density test finds that 3 of 17 thresholds show evidence of manipulation, but results are robust to dropping those thresholds from the stacked analysis.

5 Discussion and Conclusion

This paper produces three findings with different degrees of credibility.

The most credible finding is that the cross-sectional correlation between FPM bracket assignment and crop area predates the FPM transfers themselves. Pre-period placebo estimates are virtually identical to post-period estimates, indicating systematic selection of agricultural municipalities into higher population brackets. This is an important methodological lesson for the broader literature using FPM thresholds as instruments: pre-trend analysis is essential, and cross-sectional RDD results at FPM thresholds should be reported alongside pre-period tests.

The second finding—suggestive but not definitive—is that municipalities crossing FPM brackets between censuses experienced modestly higher crop-area growth, with a marginally significant intensive-margin estimate of 2.9% per bracket ($p = 0.064$). Quantitatively, a typical one-bracket crossing (R\$0.8 million windfall) is associated with roughly 440 additional hectares at the sample mean—an economically plausible if small response for municipal governments that can fund rural roads, storage, or agricultural extension. The panel design

removes time-invariant heterogeneity, but cannot fully rule out that bracket crossings are correlated with broader growth dynamics.

The third pattern—heterogeneity by biome—is descriptively interesting but requires caution. The cross-sectional gap at FPM thresholds is much larger in Amazon municipalities than non-Amazon municipalities, which is consistent with a mechanism in which transfers to frontier municipalities fund infrastructure that lowers the cost of agricultural conversion. But given the baseline sorting documented by the placebo test, this gap may partly reflect pre-existing differences in agricultural potential between Amazon municipalities above and below thresholds.

These findings speak to the fiscal federalism and land-use literatures ([Burgess et al., 2012](#); [Ferraz and Finan, 2011](#)). Brazil’s FPM was designed for equalization, not land governance. Future research using deforestation outcomes from satellite data and stronger identification of the causal effect of transfers—perhaps using annual FPM payment records merged with land-cover change data—would be a valuable extension.

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Table 1: Summary Statistics for RDD Sample

Group	N	Mean Pop. (000)	Crop Area (ha)	Log Crop Area
Above Threshold	1484	35.2	15086	8.21
Below Threshold	1534	35.4	15408	8.25
Full Sample	3018	35.3	15250	8.23

Note:

Notes: Sample is municipality-threshold pairs within the MSE-optimal bandwidth of 11.7% of each FPM population threshold. Crop area is the average area planted (hectares) of annual crops, 2005–2015, from IBGE PAM. “Above Threshold” indicates municipalities whose 2000 census population exceeds the relevant FPM threshold. Brazil has 17 FPM population thresholds; the stacked dataset includes each municipality once per nearby threshold.

Tables

Table 2: FPM Thresholds and Agricultural Expansion: Multi-Cutoff RDD

	Full Sample	Non-Amazon	Amazon
Above FPM Threshold	-0.224 (0.146)	-0.291* (0.156)	0.853** (0.353)
Observations	3018	2743	274
R ²	0.023	0.023	0.257
Threshold FE	Yes	Yes	Yes
Bandwidth	11.7%	11.7%	11.7%

Notes: Dependent variable is log average crop area (hectares) planted, 2005–2015. Sample is municipality-threshold pairs within the MSE-optimal bandwidth (11.7% of threshold). “Above FPM Threshold” indicates municipalities whose 2000 census population exceeds the relevant FPM population cutoff, entitling them to a higher FPM coefficient (0.2 increment). All specifications include threshold fixed effects and local linear polynomials on each side with triangular kernel weights. Amazon states: AC, AM, AP, PA, RO, RR, TO. Standard errors clustered by municipality. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Panel DiD: Municipalities Crossing FPM Thresholds, 2000–2019

	Binary	Intensive Margin	Amazon
Crossed Threshold \times Post-2010	0.030 (0.022)		-0.134 (0.084)
Brackets Crossed \times Post-2010		0.029* (0.016)	
Observations	105675	105675	8516
R ²	0.904	0.904	0.778
Municipality FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: Dependent variable is log annual crop area planted (hectares). Sample: municipalities in the same FPM bracket across both censuses (stayed) or that crossed to a higher bracket between 2000 and 2010 (crossers). “Crossed Threshold” = 1 if a municipality moved to a higher FPM bracket between the 2000 and 2010 censuses. “Brackets Crossed” is the number of brackets gained. All specifications include municipality and year fixed effects. Crossers: 1,357 municipalities. Stayers: 4,015 municipalities. Annual data: 2000–2019. Column (3) restricts to Amazon-biome states. Standard errors clustered by municipality. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Bandwidth Sensitivity and Density Tests

<i>Panel A: Bandwidth sensitivity (stacked multi-cutoff OLS)</i>			
Bandwidth	N (obs.)	Estimate	(SE)
10%	2,543	-0.2284	(0.1580)
15%	3,858	-0.2079	(0.1285)
20%	5,286	-0.1783	(0.1072)
25%	6,694	-0.1418	(0.0940)
30%	8,194	-0.1263	(0.0825)
<i>Panel B: Density test for manipulation at thresholds</i>			
Thresholds significant at p<0.05	3 of 17		
Thresholds with manipulation	1, 3, 17 (pop. 10,189; 16,981; 156,217)		

Notes: Panel A shows the stacked multi-cutoff OLS estimate of crossing an FPM population threshold on log crop area, varying the kernel bandwidth as a fraction of each threshold value. Triangular kernel weights and threshold fixed effects throughout. The main specification uses the MSE-optimal bandwidth of 11.7%. Standard errors clustered by municipality. Panel B reports McCrary-style density tests (`rddensity`) at each of the 17 FPM thresholds individually. Only 3 of 17 thresholds reject the null of no manipulation at the 5% level, providing limited evidence of systematic sorting into higher FPM brackets.

Table 5: Robustness Checks: Donut-Hole and Pre-Period Placebo

	Main	Donut ($ x < 1\%$)	Pre-period Placebo
Above FPM Threshold	-0.224 (0.146)	-0.354* (0.184)	-0.226* (0.134)
Observations	3018	2721	3012
Threshold FE	Yes	Yes	Yes
Period	2005–2015	2005–2015	2000–2004

Notes: All specifications use the stacked multi-cutoff dataset with triangular kernel weights and threshold fixed effects. Column (1) repeats the main specification from Table 2. Column (2) excludes municipality-threshold pairs within 1% of each cutoff (donut-hole test for manipulation). Column (3) uses average log crop area in 2000–2004 as the outcome; a significant estimate here would indicate pre-existing differences at the threshold. The pre-period placebo estimate is comparable in magnitude to the main estimate, suggesting baseline sorting that limits causal interpretation of the cross-sectional RDD. The panel DiD (Table 3) addresses this by using within-municipality variation. Standard errors clustered by municipality. *** p<0.01, ** p<0.05, * p<0.1.

A Standardized Effect Sizes

Table 6: Standardized Effect Sizes: FPM Thresholds and Agricultural Expansion

Outcome	$\hat{\beta}$	SE	SD(Y)	SDE	SE(SDE)	Classification
Log Crop Area (Full Sample, RDD)	-0.2237	0.1465	1.8166	-0.1232	0.0806	Moderate negative
Log Crop Area (Non-Amazon, RDD)	-0.2911	0.1556	1.8545	-0.1570	0.0839	Large negative
Log Crop Area (Amazon, RDD)	0.8532	0.3526	1.3541	0.6301	0.2604	Large positive
Log Crop Area (Panel DiD, Binary)	0.0296	0.0215	1.7355	0.0171	0.0124	Small positive
Log Crop Area (Panel DiD, Intensive)	0.0292	0.0157	1.7355	0.0168	0.0091	Small positive

Notes: Country: Brazil. Research question: Does crossing a higher FPM (Fundo de Participação dos Municípios) population threshold — which triggers a discrete increase in federal-to-municipal fiscal transfers — cause municipalities to expand agricultural production (as measured by annual crop area)? Policy mechanism: Brazil’s FPM distributes federal income tax revenue to all 5,570 municipalities using a coefficient schedule with 17 population thresholds; crossing a threshold raises the municipality’s transfer coefficient by 0.2 (out of a typical total of 0.6–4.0), yielding an annual windfall of approximately R\$0.8 million. Outcome: Log area planted (hectares) of annual crops from the IBGE Pesquisa Agrícola Municipal (PAM), averaged 2005–2015 for the cross-section (RDD), or annual 2000–2019 for the panel (DiD). Treatment: Binary indicator for municipality 2000 census population exceeding an FPM threshold (RDD); or binary/count of brackets crossed between 2000 and 2010 censuses (panel DiD). Data: IBGE PAM (annual crops, 109,493 municipality-year obs.); IBGE Census 2000/2010. Method: Cross-sectional stacked multi-cutoff OLS with triangular kernel weights, threshold fixed effects, local linear polynomial on each side of cutoff; clustered standard errors by municipality. Panel specifications use municipality and year fixed effects. Sample: Full sample, Amazon-biome subgroup (AC, AM, AP, PA, RO, RR, TO), and non-Amazon municipalities. Classification refers to magnitude of standardized effect size, not statistical significance.

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