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Investing in local capacity to respond to a federal environmental mandate: Forest & economic impacts of the Green Municipality Program in the Brazilian Amazon

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ABSTRACT

Over the past decade, the Brazilian federal government has offered a negative collective incentive to reduce deforestation by 'blacklisting' the municipalities in the Amazon with the highest deforestation rates. As for any unfunded mandate, the responses to blacklisting depend on both local incentives and local capacities. We evaluate a state program – Programa Municípios Verdes (PMV) or the Green Municipality Program – to increase the capacity of municipal governments in the state of Pará to respond to this federal incentive. The PMV is voluntary, as municipal governments choose whether to participate. To control for differences due to self-selection into the program, we employ quasi-experimental methods: two-way, fixed-effects regressions in matched samples of municipalities; and the synthetic control method that compares outcomes in a participating municipality to outcomes in a weighted blend of control municipalities. Neither approach suggests that the PMV reduced deforestation beyond the effect of the blacklist. We hypothesize that municipalities joined the PMV to ameliorate the costs of complying with blacklist requirements, including the costs of exiting the blacklist. We show that the PMV increased total value added – with substantial heterogeneity - in participating blacklisted municipalities, and that these gains likely are not due to agricultural intensification. They may result from reductions in compliance risk and cost that make economic investments in a municipality more appealing. In the long run, this could make forest conservation more socially and politically sustainable.

1. Introduction

The remarkable reduction in deforestation in the Brazilian Amazon during the late 2000s (Tollefson, 2015) has been largely attributed to national policies, including protected areas as well as increased monitoring and enforcement of federal laws that limited conversion of private forested parcels. Starting in 2008, enforcement targeted rural producers in the municipalities with the highest rates of deforestation, which were placed on a priority list or "blacklist" – a form of spatial targeting that has been found to effectively reduce deforestation (Arima, Barreto, Araújo, & Soares-Filho, 2014; Assunção, McMillan, & Souza-Rodrigues, 2019; Assunção and Rocha, 2019; Cisneros, Zhou, & Börner, 2015; Koch, zu Ermgassen, Wehkamp, Oliveira Filho, & Schwerhoff, 2019). The 'blacklist' policy was also expected to effectively decentralize efforts to control deforestation (Neves, Costa, & Whately, 2016) by offering a collective incentive for local governments and producers to comply with federally chosen limits on deforestation in a way that minimizes local costs. The need for incentives to induce local investment in environmental public goods in decentralized systems of natural resource governance is well recognized (Sunderlin et al., 2015; Tacconi, 2007; Weibust, 2016).

Responses by local governments facing such incentives are expected to depend on local governance capacity, as well as the net benefits or costs to local constituents. Programs have emerged to help build up local governance capacity and generate local co-benefits. For example, in the context of global incentives to reduce forest-carbon emissions under REDD+, both multilateral and bilateral institutions have invested heavily in local governance capacity, as well as in benefit-sharing systems within tropical forest countries, under the umbrella of "REDD + Readiness" (Dunlop & Corbera, 2016; Minang et al., 2014). Analogously, within domestic

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policy, a state government in the eastern Brazilian Amazon, Pará, has sought to increase the capacity of local governments to respond to the federal blacklist through a "Green Municipality Program" (or Programa Municípios Verdes (PMV)).

The PMV was established by the governor of Pará as a special program in his office in 2011, although it did not have its own budget until being awarded a large grant from the Amazon Fund in 2014. Our evaluation focuses on this initial time period (2011–2014), when the program operated primarily by coordinating the actions of state and federal agencies as well as civil society to support and build the capacity of municipal governments to control deforestation. From an institutional perspective, this strengthened the vertical relationship between local, state, and national governments within the decentralized system for regulating land use established by the Brazilian constitution (cf., Andersson, Gibson, & Lehoucq, 2006; Andersson & Ostrom, 2008). The PMV was modeled in part on the prior experience of Paragominas, which became the first municipality to exit the federal blacklist after the mayor formed an alliance with large agricultural producers to re-brand the municipality as "green" (Sills et al., 2015; Thaler, Viana, & Toni, 2019; Viana et al., 2016). In addition to that perceived success, motivations for the PMV included the blacklisting of many other municipalities within the state of Pará and pressure from the Public Prosecutor's Office (Ministério Público Federal or MPF) to address illegal deforestation.

The PMV's stated objective is to reduce deforestation, i.e., to achieve lower deforestation rates than would have been achieved by national policies alone. Political leaders of the PMV have recognized that to sustain reductions in deforestation over the long run, it is critical to find economic development pathways compatible with forest conservation (Zwick, 2017). Thus, we evaluate whether participation in PMV reduced deforestation and whether it improved economic outcomes in municipalities operating under the constraints of the federal blacklist. Specifically, we estimate fixed-effects regressions in matched samples of municipalities to identify the average effects of the PMV on both deforestation and economic outcomes, differentiating units by blacklist status. The estimated effects of the PMV are statistically significant only in blacklisted municipalities. We unpack those average effects by employing the synthetic control method to identify effects specific to each blacklisted municipality in the PMV, finding substantial heterogeneity across municipalities.

In the next section, we provide more background on the PMV including its theory of change. In the rest of the paper, we describe data, empirical methods, and findings from our rigorous impact evaluation of the forest and economic effects of the PMV.

2. Theory of change

The PMV is a program of the state government of Pará that is open only to municipalities in Pará.[1] It was launched in conjunction with legal settlements (TCs or termos de compromisso) that municipal governments signed with the MPF as a remedy for illegal deforestation. Indeed the PMV automatically enrolled the 39 municipalities that had signed TCs prior to the 2011 launch of the PMV. Municipalities could also join the program by signing memoranda of cooperation (MCs or termos de cooperação), directly with the PMV, either in addition to or instead of having TCs. By July of 2014,[2] the program had signed up another 65 municipalities through one or both of these mechanisms.

[1] Civil society organizations have supported similar sustainable development programs for local governments in other states in Brazil (e.g. Thaler et al., 2019) as well as other countries (e.g., Lingkar Temu Kabupaten Lestari in Indonesia).

[2] A given year X in our database begins in August of the previous year (X-1) and ends in July of the current year (X), for consistency with annual deforestation as monitored and reported by INPE, the National Institute for Space Research.

Municipal governments decide whether to affiliate with the PMV. As they are led by local politicians beholden to local groups, including some that benefit from local deforestation (Bowman et al., 2012; Mullan, Sills, Pattanayak, & Caviglia-Harris, 2017), their participation decisions are unlikely to be motivated by the nominal "green" aims of the PMV. Rather, they are likely to join in order to obtain assistance avoiding the penalties and restrictions imposed by the federal government on blacklisted municipalities. Complicating the task of attribution, many of the factors that influence this municipal decision to join the PMV could also influence deforestation and economic outcomes, including historical deforestation rates and socioeconomic development, environmental governance capacity, political alignment with the state government, the role of agriculture in the local economy, federal pressure to control deforestation, infrastructure, and land use designations such as protected areas.

The PMV lays out seven steps for participating municipalities: (1) establish a (non-binding) social pact to reduce deforestation rates; (2) establish a working group to monitor deforestation; (3) register 80% of the land in the municipality (outside of protected areas) in the rural environmental cadaster called the Cadastro Ambiental Rural or CAR (Duchelle et al., 2014), as required to exit the blacklist; (4) lower and keep deforestation below 40 square kilometers per year, as required to exit the blacklist; (5) carry out checks in the field in response to deforestation alerts; (6) not be in the blacklist; and (7) establish an environmental governance structure, including a council, fund, and system for environmental licensing. While these steps could, in principle, lead to reductions in deforestation beyond federal mandates, the PMV clearly focuses on controlling deforestation sufficiently to stay off or to get off the blacklist (Santos, de Almeida, Lacerda, Silva, & Brito, 2016).

One way that the PMV pursues this objective is to engage affiliated municipal governments in enforcement of federal forest regulations. The PMV seeks to take advantage of municipal governments' close relationships with local producers, especially large holders who are likely to be well connected to local political elites. Government officials at the municipal level can make the case to these producers that, given the blacklist, it is in their interest to not deforest illegally. Municipal governments could also lower costs of CAR registration by establishing a system that is locally accessible and locally adapted, thereby increasing registration and making the CAR a more effective instrument for enforcement. Finally, municipal governments can more easily respond to deforestation alerts than can the distant state and federal authorities. These mechanisms lower the costs of compliance with federally established limits on deforestation.

The PMV also offers technical support (including information, training, equipment, and improved communications with environmental agencies) that reduces the costs of solving the collective-action problem that is created by the blacklist. Individual landowners in the municipality expect positive net benefits from deforestation but, as a whole, they suffer from the collective penalties imposed by the federal government upon the municipalities with the highest deforestation. The first goal of the PMV directly addresses this collective action problem by calling for an agreement with all local business sectors and other stakeholders to reduce deforestation. To accomplish this and other goals, the program offers in-kind support to municipal governments, e.g., template agreements, GPS units and digital base maps. Further, the PMV administers a "Green VAT" program, which allocates a portion of value-added tax revenues to municipalities (that are officially designated for municipal environmental programs) based on their progress reducing deforestation and registering properties in the CAR and the fraction of their territories in protected areas. This program only got under way at the end of our study period, however, with an initial allocation of just 2% of total tax revenues distributed to the municipalities in 2014 – although this percentage was to increase over time.

In addition to its primary objective of controlling deforestation, the PMV also has a stated objective of promoting sustainable rural production (PMV, 2018). Rather than using direct fiscal transfers such as the Green VAT, the PMV pursues this goal through a series of actions that reduce rural production costs. Specifically, the program helps municipalities bring producers into environmental compliance, e.g., by registering their properties in the CAR as is required in order to sell to the major beef and soybean buyers operating under their legal settlements with the MPF (termos de ajustamento de conduta). The PMV and MPF help municipalities in the program to obtain varied forms of support from government agencies such as INCRA – the National Institute of Colonization and Agrarian Reform (to register land), IBAMA – the Brazilian Institute of Environment and Renewable Natural Resources (to forestall environmental embargos in municipalities coming into compliance with the PMV), and the Ministry of Agriculture (to obtain technical and financial assistance for 'low carbon agriculture'), as well as financial institutions (to guarantee producers access to credit and assist local governments with financing infrastructure). The latter two types of support are intended to help intensify production on already deforested lands. This is consistent with efforts by international civil society (zerodeforestationcattle.org) and the Brazilian government (Bogaerts et al., 2017) to promote intensification of cattle production as a strategy for reducing deforestation. The logic of this strategy is that maintaining output levels while reducing deforestation will prevent market feedbacks that might otherwise undermine efforts to control deforestation (e.g., Cohn et al., 2014; de Waroux et al., 2017).

Finally, participation in the PMV could improve the image of a municipality and reduce the risk that individual producers or the entire municipality will face restricted access to markets for environmental reasons, through either judicial or supply-chain actions. When combined with reduced transactions costs of environmental compliance, this could arguably eventually make the municipality more attractive for all types of investments, including some outside of agriculture. Thus, this potentially helps to diversify the economy and to mitigate the local economic costs of the restrictions imposed by the federal government on blacklisted municipalities and the synergistic actions of the MPF.

In order to quantify the impacts of the PMV, we must identify some specific measurable outcomes. The primary stated objective of the PMV can be represented as the annual deforestation rate within a municipality. Sustainable rural production embeds various goals but is ultimately reflected in the value added generated per year in a municipality. Within the Brazilian fiscal system, value added also largely determines the size of transfers to municipal governments. To assess one possible mechanism for increasing value added, we also evaluate the impact of the PMV on intensification in the agricultural sector. Sources of data on these outcomes are considered in the following section.

3. Data

3.1. Sample & timeframe

Our unit of analysis is the municipality, delimited using the official municipal boundaries of 2013. All of the treated municipalities are in the state of Pará. We compare them to similar municipalities that are not in the program, from throughout the Amazon forest biome – when we are considering either forest or agricultural intensification outcomes – and from the three states with the most active deforestation frontiers – when we are considering the value-added outcome (Fig. 1).[3] As explained below, we focused on obtaining value added data from the three states where our preliminary analysis suggested that we would find the most suitable controls for the municipalities in the PMV program. We evaluate the impacts of the PMV during its first phase, from 2011 to 2014.

3.2. Treatment

We define treatment as affiliation of a municipal government with the PMV, i.e. signing up for the PMV or "participation." Of the 144 municipalities in Pará, 104 affiliated with the PMV between 2011 and 2014, according to PMV's online database (PMV, 2018)[4]. We exclude from our analysis the municipalities that joined more recently, as well as Paragominas (the latter because it was the model for the program and had, therefore, already been "treated" before the PMV program began).

Year of treatment is defined according to when the PMV considered a municipality to be affiliated, based on either a legal settlement (TC) with the MPF or a memorandum of cooperation (MC) with the PMV. By July 2011, the MPF had signed TCs with 90 municipalities in Pará, hence all of those municipalities are considered treated in 2011. Some (but not all) of those municipalities also signed MCs with the PMV. Another 14 municipalities joined PMV by July 2014, some by TCs, some by MCs, and some by both mechanisms. We test our fixed effects model for sensitivity to re-defining treatment as either (1) signing a TC and thereby joining the PMV by July 2012, excluding 13 municipalities that joined later, or (2) signing a TC at any time during the study period, including a control for whether a municipality had signed a MC. We find qualitatively similar results for all three definitions of treatment in fixed effects regressions estimated in the same matched sample. This is not surprising, as 90 out of 104 municipalities are 'treated' in all three definitions.

Ten municipalities that signed up for the PMV also received technical assistance (e.g., training in GIS, new computer systems for the CAR) from a civil society organization that was working with the PMV (Imazon, 2018). We do not distinguish that organization's effort as a separate treatment. Yet, we do confirm that our results are robust to including a control for these ten municipalities.

3.3. Outcomes

3.3.1. Deforestation

The Brazilian government tracks deforestation (including for the purposes of defining the blacklist and reporting to Amazon Fund donors) through the INPE PRODES project (PRODES, 2018). PRODES provides spatially explicit information (with a minimum mapping area of 6.25 ha) on annual rates of deforestation since 2000, as shown in Fig. 1. We used the PRODES deforestation polygons to calculate square kilometers deforested in each municipality in each year, distributing deforestation polygons that were previously under cloud cover evenly across the years when clouds were present.[5] To account for the enormous variation in the size of

[3] We define "in the biome" as (i) fully contained within the Amazon Biome boundary published by IBGE or (ii) crossed or bordered by the Amazon Biome boundary and originally at least half under forest cover.

[4] Specifically, we consider municipalities to be treated if they affiliated with the program by July of 2014, which is also when the PMV was converted into a permanent program, with funding from the Amazon Fund administered by the *Núcleo Executor do Programa Municípios Verdes*.

[5] Deforestation polygons coded by PRODES as 'DSF_ANT" in the states of Amapá and Maranhão were treated as deforestation prior to 2000. PRODES also provides estimates of deforestation by municipality, and those are highly but not perfectly correlated with our estimates, likely due to different methods for allocating deforestation that appears under cloud cover. Changes in the geo-rectification of the 2015 release of the data resulted in some differences in the spatial distribution of deforestation reported in 2012 and earlier as compared to 2013 and 2014 due solely to that change in georectification (INPE, 2015).

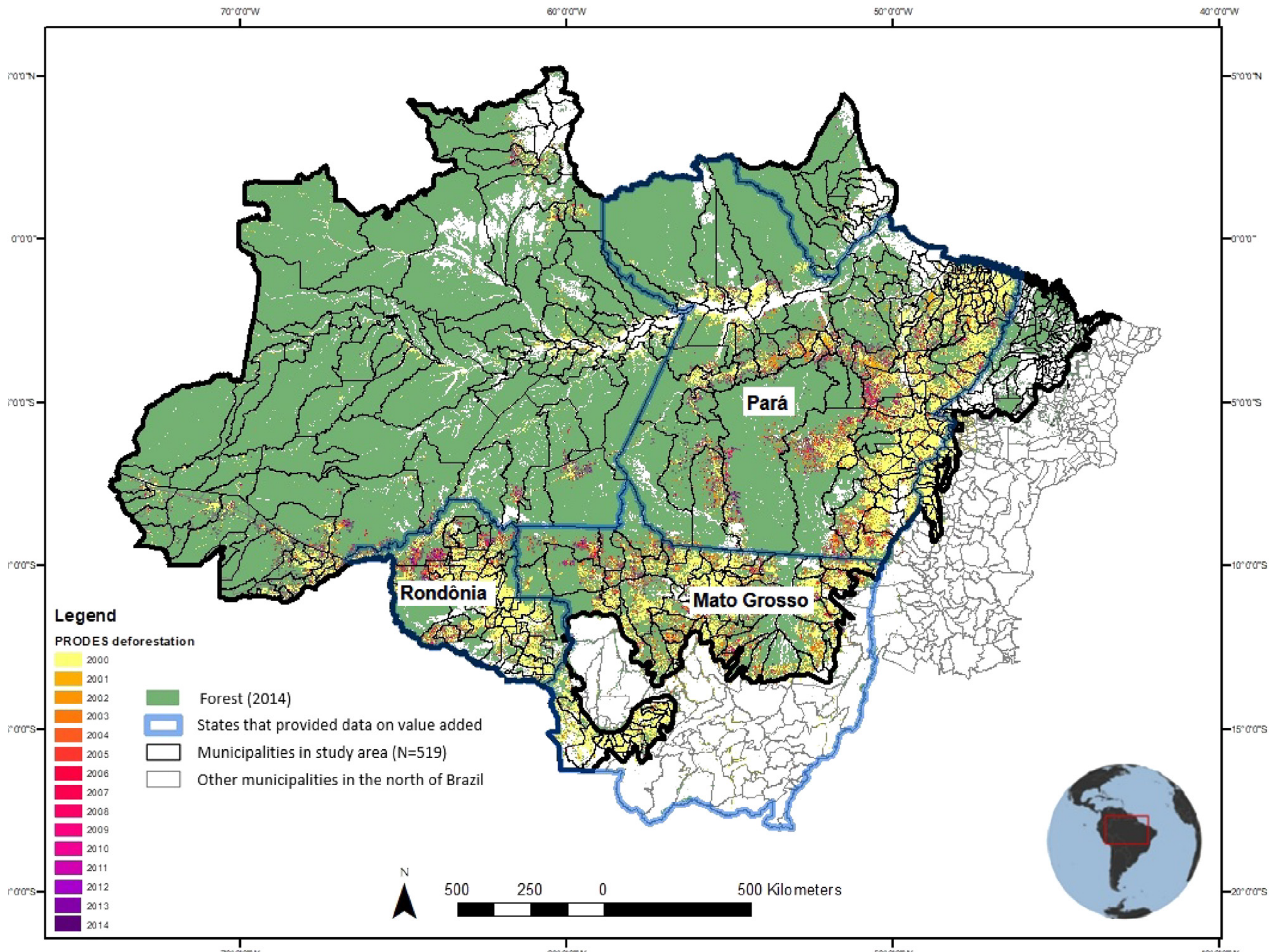


Fig. 1. Amazon forest biome: study area and deforestation.

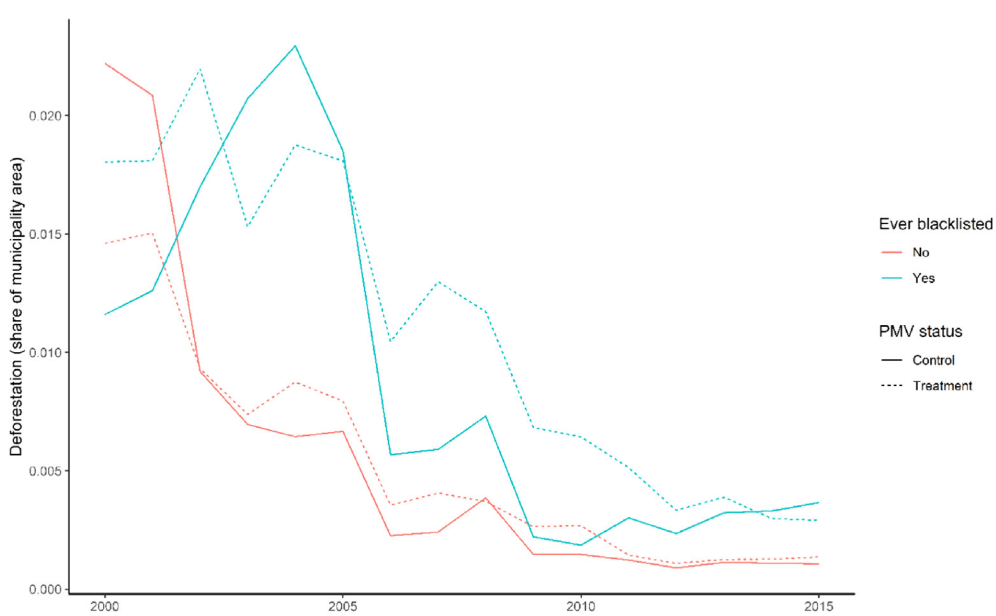


Fig. 2. Trends in Deforestation by Type of Municipality.

municipalities, we divide the square kilometers deforested by the square kilometers of land in the municipality to obtain annual percent deforestation. The average annual percent deforestation is plotted in Fig. 2 for four groups of municipalities defined by whether they were ever blacklisted and whether they ever joined the PMV.

3.3.2. Value added

To measure economic activity in municipalities, we rely on an indicator calculated annually as part of the Brazilian tax system. We prefer it to GDP for our analysis as there is a break between 2010 and 2011 in the time series on GDP, due to a methodological change. Since municipal governments can only directly raise revenue through taxes on services, urban properties, and property transfers, their budgets are almost entirely determined by transfers of 25% of the value-added tax, or ICMS (*Imposto Sobre Operações Relativas à Circulação de Mercadorias e Serviços*).[6] Brazil's constitution specifies that 75% of these transfers are to be distributed to municipalities based on the share of tax revenue that they generate or *Valor Adicionado Fiscal* (VAF). Brazilian states have applied different criteria to allocate the remaining 25%, using factors such as school attendance rates, population, and land area.

We requested annual data on the VAF from all the states in the Amazon, most vigorously pursuing the data from Pará and from the two states with municipalities included with non-zero weights in synthetic controls (explained below) when we analyzed the total ICMS transfers.[7] We do not use these total transfers to evaluate impacts because they reflect distributional concerns in addition to the local economic activity that is our focus. Thus, we use data on the annual VAF from 2002 to 2014 of municipalities in the states of Pará, Rondônia, and Mato Grosso. We drop 11 municipalities with large cities or mineral/energy production including a treated municipality (Marabá) that has the largest iron ore mine in the Americas and therefore an exceptionally high VAF[8]. In Fig. 3, we plot average annual VAF for the same categories of municipalities portrayed in Fig. 2, for these three states.

3.3.3. Agricultural intensification

We also consider a potential mechanism by which the PMV could affect total value added. As noted above, there has been substantial policy interest in increasing agricultural yields in already deforested areas as a complement to restrictions on expanding the agricultural area (cf., Koch et al., 2019 for the effects of the blacklist on intensification). Such intensification could increase sectoral employment, income per hectare and, thereby, valued added. We therefore examine intensification within key systems (crop yields, pasture stocking) and the areas allocated to systems with different capital and labor requirements (perennial crops, annual crops, and pasture), using data from the national census bureau (IBGE).

3.3.3.1. Pasture stocking. We calculate the 'pasture stocking ratio' (i.e., the total head of cattle divided by the pasture area) for each municipality in each year from 2008 to 2014. It is higher in the blacklisted municipalities. Head of cattle are reported by IBGE in the annual Pesquisa Pecuaria Municipal, or PPM. The Mapbiomas project reports area of pasture in each municipality based upon remote sensing (Mapbiomas, 2018)[9].

3.3.3.2. Crop intensities. The average values of production per hectare in perennial crops (notably açai, banana, black pepper, cocoa, and orange) and average values of production per hectare in annual crops (dominated by cassava, rice, maize, soy and sugarcane) are extracted from the annual Pesquisa Agricola Municipal (PAM) for 2002 to 2014 and deflated to the year 2002 using the GDP deflator. Perennial yields tend to be higher in forested municipalities, while annual crop yields tend to be higher in more deforested municipalities on the old frontier. We use total value of production per hectare in annuals and in perennials (rather than values of individual crops) as the most consistent and relevant measure.

3.3.3.3. Land shares. Perennial crops, either in plantations or agroforestry systems, have long been promoted as a way to stabilize the deforestation frontier in the Amazon, because they require relatively more capital and labor inputs and potentially have higher production values per hectare. We therefore also examine the area planted in perennial crops, versus the area planted in annual crops and the area of pasture (i.e. the denominators of an intensification measures), as a potential mechanism for increasing VAF while controlling deforestation. Perennial crops occupy a small percentage of Amazonian land area.

3.4. Covariates

We compile data on covariates for two types of matching (Tables 1a and b). For nearest neighbor matching to select a sample balanced across PMV participants and non-participants, we identified covariates that proxy for the factors that we expect to influence the choice to affiliate with the PMV. We proxy historical deforestation and development using deforested area, population density, GDP per capita, and educational achievement. We proxy local capacity for environmental governance with a count of how many of the following were reported in IBGE's MUNIC survey in 2009: municipal agency dedicated to the environment; environmental council; council met in 2009; environmental fund; environmental fund active in 2009; environmental licensing; and cooperation with state-level environmental licensing.

We measure the political alignment between the state and municipal governments with an indicator of whether the municipal mayor was from the same political party (PSDB) as the governor of the state who created the PMV. The importance of agriculture to the local economy is represented by the number of agricultural establishments, percent of GDP from agriculture, an indicator for whether a municipality was free from phytosanitary restrictions related to foot and mouth disease, and share of land area in agricultural colonization settlements. Pressure from the federal government to control deforestation is captured by whether the entire municipality was blacklisted, as well as by the fraction of the municipal area that was under embargo due to environmental infractions. Finally, we include the fractions of the municipality that are in federal protected areas, in indigenous territories, and within 5 km of a road, all of which have been identified as key determinants of local patterns of deforestation.

For synthetic control matching, we add covariates related to the outcomes of interest (e.g. credit, mines, elevation, and slope) and drop covariates not theoretically related to outcomes (e.g., political alignment). We prioritize variables available for all years in the pre-treatment period used to generate synthetic controls (e.g., total head of cattle rather than stocking rate, slaughterhouses rather than phytosanitary conditions to measure access to agricultural markets, and sectoral shares of tax revenue from the Ministry of Finance rather than GDP by sector from IBGE). All of these covariates are derived from publicly available data (Tables 1a/1b) for years prior to PMV's start in 2011.

[6] Municipalities in the Amazon also benefit from the *Fundo de Participação Municipal* that re-distributes federal income, industrial, and rural property tax revenues to relatively low-income regions.

[7] Data on ICMS transfers to the municipalities are available from the federal government. When we analyzed these total transfers, almost all municipalities matched to treated (PMV) municipalities were from the states of Pará, Mato Grosso, and Rondônia. Minor exceptions were one municipality each in Roraima and Maranhão that were matched to a single municipality in the PMV, and one municipality in Amazonas that was matched to multiple municipalities in the PMV. We requested, but did not follow-up as persistently on VAF data from AM, MA, and RR.

[8] The municipalities dropped from the analysis are Ananindeua, Barcarena, Belem, Canaa dos Carajas, Espigao d'Oeste, Marabá, Parauapebas, Porto Velho, Sao João da Ponta, Tucurui and Sorriso.

[9] We used the first release of Mapbiomas data. They have now released additional data collections, covering the years 2000 to 2018.

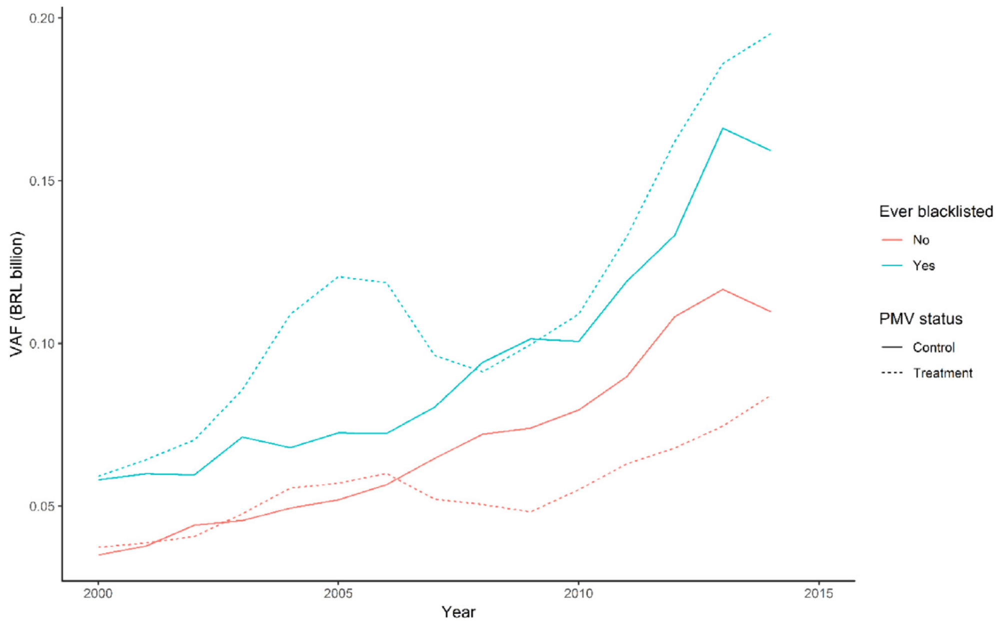


Fig. 3. Trends in Value Added by Type of Municipality (in the states of MT, PA and RO).

Table 1a
List of covariates used for nearest neighbor matching.

Method	Variable	Description (source)
Matching	Ever blacklisted	=1 if ever had been blacklisted prior to 2011 (MMA)
Both	Number of local environmental institutions in place in 2009	Count of indicators for municipality agency dedicated to the environment; environmental council; council met in 2009; environmental fund; environmental fund active in 2009; offered local environmental licensing; cooperated with state-level environmental licensing (IBGE – MUNIC)
Both	Share of indigenous reserves area in 2009	Area in indigenous territories (FUNAI) divided by municipal area
Both	Share of protected area in 2009	Area in protected areas (IBAMA) divided by municipal area
Both	Number of agricultural establishments in 2006	Number of rural properties divided by municipal area (IBGE)
Both	Share of Incra settlements in 2009	Area in INCRA settlements (INCRA) divided by municipal area
Matching	Occurrence of foot and mouth disease in 2009	=1 if not subject to phytosanitary restrictions (no occurrence of foot & mouth disease) (Min.Agriculture)
Both	Education HDI in 2009	Education component of the human development index (PNUD)
Both	Share of embargoed area in 2009	Area under IBAMA embargo (IBAMA) divided by municipal area
Matching	Share of agriculture in GDP in 2009	Agricultural income divided by municipal income (Sec.Finance)
Both	Road density in 2008	Area < 5 km of official or unofficial roads (Imazon) divided by municipal area
Matching	Mayor belonged to governor's party in 2008	=1 if mayor from the PSDB (party of the governor) (TSE)
Matching	GDP per capita in 2003	GDP per capita (IBGE)
Matching	Population density in 2000	People per km2 (IBGE)
Both	Share of deforested area in 2000	Area deforested in 2000 (PRODES) divided by area of municipality
Matching	Cattle Stocking Ratio	Head of cattle (PPM) divided by pasture area (MapBiomas)

Table 1b
List of additional covariates used for synthetic control method.

Method	Variable	Description (source)
SCM	Average Elevation	Meters
SCM	Average Slope	Degrees
SCM	Cattle	head of cattle (PPM – IBGE)
SCM	Conflict % of Area	area identified as in conflict divided by municipal area (CPT)
SCM (VAF)	Credit	value of credit provided to municipality (BACEN)
SCM	Mines Density	# mines divided by municipal area
SCM	Slaughterhouse	1 if at least one large slaughterhouse in municipality, 0 otherwise
SCM (VAF)	Agriculture % of GDP	GDP from agriculture divided by municipal GDP (Sec.Finance)
SCM (VAF)	Industry % of GDP	GDP from industry divided by municipal GDP (Sec.Finance)
SCM (VAF)	Services % of GDP	GDP from services divided by municipal GDP (Sec.Finance)
SCM (VAF)	Urban % of Area	area classified as urban (IBGE) divided by municipal area

In addition to matching on blacklist status, we control for it in fixed-effects regressions as well as in our definition of the donor pool for synthetic controls. Across the entire Amazon, 60 municipalities have been blacklisted at some time, including 52 during the time period of our study.[10] We consider the year a municipality entered the blacklist and, if relevant, the year that it exited. Fig. 2 confirms deforestation was substantially higher in blacklisted municipalities, as expected per blacklisting rules.

4. Empirical approaches

4.1. Fixed effects panel analyses

To estimate the effect of joining the PMV on deforestation, or on the municipal economy, we start by combining all municipalities in our sample (the Amazon forest biome for deforestation and three states for value added) as well as all years in our data (2000 or 2002–2014) in order to estimate panel models with fixed effects for municipalities and years. The dependent variables are annual deforestation as a percent of the municipality, value added in the municipality measured as VAF, and several indicators of agricultural intensification as potential mechanisms for increasing VAF. Since we know that affiliation with the PMV is motivated in part by the threat of the blacklist – and more generally, it is quite widely believed that the blacklist affects both municipal economies and land use – we include an indicator of blacklist status and two interaction terms. The first interaction term (with 'PMV ever') controls for the effect of blacklisting in municipalities that would eventually join the PMV, for example, in municipalities that were blacklisted in 2008. This interaction term captures the drop in VAF following blacklisting in the municipalities that would later join the PMV, as shown in Fig. 3. The second interaction term (with 'PMV active') represents the effect of the PMV in blacklisted municipalities. We estimate these specifications for deforestation, VAF, and measures of agricultural intensification. Assuming parallel trends over time in the outcome (more below), the coefficient on 'PMV active' (by itself for non-blacklisted municipalities and added to the coefficient on the interaction term for blacklisted municipalities) provides a valid estimate of the effect of the PMV. In a second specification of the models of deforestation and VAF, we replace PMV and 'PMV active' with indicators for each year in the program in order to test for changes in the effect sizes over time.

4.2. Matching

4.2.1. Covariate matching before panel estimation

To increase the similarity of our controls to our treated municipalities, we apply covariate matching to identify a sub-set of control municipalities (that never joined PMV) that is better balanced on key covariates with the set of all treated municipalities. By combining matching with fixed-effects panel regression, we control for multiple potential sources of bias including both observed and unobserved factors (Jones & Lewis, 2015). Specifically, we use covariate matching with the Mahalanobis metric to select the control municipalities that are most observationally similar (Abadie & Imbens, 2006). We choose "nearest neighbors" with replacement: a control municipality found to be most similar for one treated municipality is put back in the pool for consideration for all of the other treated municipalities and could be chosen as a control for more than one municipality. We do this to identify: (i) the single best match, i.e., the single "nearest neighbor", and (ii) the five best matches, for each treated municipality. For the VAF, we start with the pool of all municipalities in the Amazon forest biome in Pará, Mato Grosso, and Rondônia, while for deforestation and agricultural intensification, we start with all of the municipalities in the Amazon forest biome (Fig. 1).

To assess whether matching improves balance, we consider the standardized differences in means of the matching covariates (supplemental materials, Tables 1 and 2). To assess whether the improved balance ensures parallel trends, we estimate our fixed effects model on pre-treatment outcomes, reporting the estimated "effect" of PMV treatment in each year prior to treatment (supplemental materials, Table 3). We find that the balance improves substantially, especially using single nearest neighbor matching. However, even in the matched sample, we are not able to confirm parallel trends in deforestation. This suggests that there are different trends over time in the PMV and non-PMV municipalities that are not swept out by fixed effects for each municipality and each year. This leads us to seek another method to better balance both the observables and the unobservables in the selected control and treated municipalities, while still allowing for heterogeneous effects over time.

4.2.2. Synthetic control method

The synthetic control method (SCM) is a municipality-by-municipality form of matching on both past outcomes and the factors that drive those outcomes. Using a nested optimization process, SCM weights those factors such that matching on them identifies the synthetic combination of municipalities that most closely followed the trends in pre-treatment outcomes in the treated municipality (Abadie, Diamond, & Hainmueller, 2010; Sills et al., 2015). This potentially improves on nearest neighbor matching by allowing for heterogeneity in the effect sizes and significance across municipalities, by considering both observed and unobserved sources of variation in the pre-treatment outcomes, and by assigning appropriate weights to the factors used as matching covariates.

Because the fixed-effects analysis and our key informants suggested that the PMV program primarily affected blacklisted municipalities, we construct synthetic controls for deforestation and VAF only in the 18 municipalities that were blacklisted at some point before they joined the PMV (excluding Paragominas, and for VAF, also excluding Marabá). We employ the nested optimization for SCM in the R package 'Synth' to search for the best-fit weighted average, across past years, from the donor pool. For deforestation, the donor pool includes all municipalities in the Amazon forest biome that were added to the blacklist in the same or a prior year and that never joined the PMV. For VAF, the donor pool includes only the blacklisted municipalities in the three states that provided data on VAF. Both donor pools exclude blacklisted municipalities in Pará, because those all eventually joined the PMV. The nested optimization starts with an expanded set of matching covariates that are believed to influence deforestation and value added (Tables 1a and 1b). The nested optimization weights those covariates such that when a matched synthetic control – or weighted combination of municipalities from the donor pool – is constructed, it follows a similar pre-treatment trajectory of the outcome. We tested different time periods for the matching, from the longest period with available data on the outcomes (since 2000 for deforestation and since 2002 for VAF) to the time period since the blacklist policy was instituted (in 2008). While lower MSPE can sometime be obtained over shorter time periods, we present results from the longest time periods available, since those are more likely to include shocks that reveal otherwise unobserved factor loadings, thus resulting in matching on long-term structural determinants of outcomes.

[10] Available at http://www.lex.com.br/legis_27508567_PORTARIA_N_361_DE_8_DE_SETEMBRO_DE_2017.aspx and http://www.lex.com.br/legis_27508568_PORTARIA_N_362_DE_8_DE_SETEMBRO_DE_2017.aspx.

We evaluate each synthetic control based on how well its weighted synthetic outcome matches the outcome value for the treated unit in the period prior to the treatment. The nested optimization minimizes the overall difference as summarized by the mean squared prediction error (MSPE). Based on plots of the outcome in the treated municipality and synthetic control (Supplemental materials), we also assess whether the synthetic control's pre-treatment time path mirrors the treated municipality's in terms of the turning points of the outcome and in terms of staying within the placebo-based confidence interval around zero (explained below). We verify that SCM improves on the balance obtained through nearest neighbor matching by computing the weighted value of each matching covariate for each synthetic control, so that those can be compared to the actual value of the matching covariate in the treated municipality. Based on these criteria, we identify a sub-set of synthetic controls that provide credible counterfactuals. As shown in Table 5, the credible synthetic controls for VAF all have MSPE < 0.0003 and for deforestation, MSPE < 0.00004.

The standard impact estimate for SCM would be the difference between the outcome in the treated municipality and the outcome in the synthetic control in the years when the treated municipality was in the PMV. However, as suggested by the higher MSPE allowed for the VAF, there are sometimes substantial differences in the VAF of the treated and synthetic control municipality immediately before treatment. Thus, for VAF, we implement a DID adjustment to SCM by subtracting from the impact estimates (i.e., the difference in actual and synthetic VAF outcomes in the years after treatment) the mean difference in outcomes in the three years prior to treatment (for most municipalities, the years between blacklisting and joining the PMV).

In order to assess whether the resulting effect estimates are significantly different from zero, we use bootstrapped placebo tests, or "bootcebos." For each year of treatment, we estimate placebo effects by "pretending" that each municipality in the donor pool was treated in that year, using the same covariates and same donor pool (and for VAF, applying the same DID adjustment described above). Because the donor pool is relatively small (<50), this gives us only a relatively small number of placebo effects to establish a confidence interval. To obtain a more continuous distribution of 'effects' of the placebo 'treatments' that also reflects variation in the donor pool, we repeat the placebo test for each municipality 100 times by drawing with replacement to create new donor pools, construct new synthetic controls, and estimate new placebo effects. In order to ensure that our bootstrapped samples include enough comparable municipalities, we use random stratified sampling to draw a sixth of the municipalities in each pool from the municipalities with the top sixth of weights in the original synthetic control. The resulting "effect" estimates for each year of pretend treatments are recorded as placebo effects, as long as the MSPE is less than twice the MSPE of the synthetic control constructed for the actual treated unit. We use the resulting set of placebo effects to establish 90% and 95% confidence intervals around zero. If an actual estimated treatment effect falls outside of the placebo-based confidence intervals, we consider it to be statistically significant.

5. Results

5.1. Fixed effects analyses

In the supplemental materials (Table 5), we provide the estimation results for two-way fixed-effects regressions (fixed effects for municipalities and years) in the full available samples. However, based on covariate balance (Table 1 in Supplemental Materials), nearest neighbor matching produces our preferred samples. We focus on the estimation results from those matched samples.

Table 2
Fixed effects model of deforestation as a function of PMV, allowing for interaction with blacklist (2 & 4) temporal effects (3 & 4).

Dependent variable:				
Deforestation (share of municipality area)				
	(1)	(2)	(3)	(4)
PMV active	0.001 (0.001)	0.002* (0.001)		
PMV: year 1			0.001* (0.001)	0.002** (0.001)
PMV: year 2			0.001 (0.001)	0.002** (0.001)
PMV: year 3			0.001 (0.001)	0.001 (0.001)
PMV: year 4			0.001 (0.001)	0.001 (0.001)
Blacklist active	−0.001 (0.001)	0.001 (0.002)	−0.001 (0.001)	0.001 (0.002)
Blacklist active * Ever in PMV		−0.002 (0.002)		−0.002 (0.002)
Blacklist active * Ever in PMV * PMV active		−0.003** (0.001)		
Blacklist active * Ever in PMV * PMV: year 1				−0.003*** (0.001)
Blacklist active * Ever in PMV * PMV: year 2				−0.003*** (0.001)
Blacklist active * Ever in PMV * PMV: year 3				−0.002 (0.001)
Blacklist active * Ever in PMV * PMV: year 4				−0.002* (0.001)
Year fixed effects	Yes	Yes	Yes	Yes
Municipality fixed effects	Yes	Yes	Yes	Yes
Observations	2848	2848	2848	2848
Adjusted R2	0.361	0.362	0.361	0.360

Notes: Matched sample of nearest neighbor municipalities in the Amazon forest biome. "PMV: year #" is an indicator for the #th year of membership in the PMV. Including indicator for Imazon technical assistance and interaction terms does not affect signs or statistical significance of coefficients on PMV and interaction terms. Standard errors are bootstrapped and clustered at municipality level. *p < 0.1; **p < 0.05; ***p < 0.01.

Table 8 in the supplemental materials provides descriptive statistics for the outcomes in the nearest neighbor matched samples.

5.1.1. Deforestation

Table 2 shows results from four different specifications of a two-way fixed effects regression model of deforestation in a matched sample of nearest neighbors. The results suggest that membership in the PMV has the perverse effect of increasing deforestation in non-blacklisted municipalities, with that effect occurring in the first one or two years of membership. In blacklisted municipalities, membership has a negative effect, reducing deforestation in the first two and last years. While estimated imprecisely (statistically significant only at the 10% level based on a Wald test), the point estimate for the full effect of participation in the PMV, obtained by summing the coefficients for PMV active and its interaction with the blacklist, is about 25% of the average deforestation rate in the participating blacklisted municipalities since 2011 (Supplemental Materials Table 8) and thus smaller but of the same order of magnitude as previous estimates of the effect of the blacklist itself (e.g., Assunção et al., 2019; Cisneros et al., 2015; Koch et al., 2019).

However, Table 3 in the supplemental materials shows the matched sample does not pass the parallel trends test: pretreatment levels of deforestation were higher in the municipalities that would later join the PMV. Further, Tables 6a, b, c in supplemental materials show that the positive effect on non-blacklisted municipalities is not robust to changes in the sample (i.e., matching on the five nearest neighbors; limiting the sample to the three states that provided VAF data; or excluding municipalities that joined the PMV late from the matched sample of nearest neighbors in the Amazon forest biome). On the other hand, the significant negative effect of the PMV on deforestation in blacklisted municipalities is robustly negative and significant across all the samples and does not change when we include a control for additional technical assistance from Imazon.

5.1.2. Value added

Table 3 presents the same four specifications of a two-way fixed effects model for VAF. In this case, the effect of the PMV is likely identified by the coefficients on the PMV and on the PMV plus its interaction with the blacklist. This is supported by the parallel trends in VAF between PMV and matched municipalities during the period of the blacklist (Table 3 in the supplemental materials) and the reasonable balance on covariates (Table 2a in the supplemental materials). Estimation results suggest no effect on municipalities that were not blacklisted (with the possible exception of a positive effect in year 4). The effect of PMV on the VAF of a blacklisted municipality is large, positive and statistically significant based on a Wald test, and grows over time. Our specification also controls for any remaining imbalance in the blacklisted subsample of our matched sample with an indicator for blacklist status, which is consistently positive and significant for municipalities that did not later join the PMV (i.e., municipalities outside Pará). Table 7 in the supplemental materials shows the effect on non-blacklisted municipalities is not robust (even changing signs) while the positive effect for blacklisted municipalities is robust to changes in sample (including matching with five nearest neighbors, and with single nearest neighbor but excluding municipalities that joined only in 2013 or 2014).

In summary, given the apparently parallel trends in VAF and reasonable balance on covariates, the fixed-effects regression results indicate that the PMV has a positive effect on the econo-

Table 3
Fixed effects model of VAF as a function of PMV, allowing for interaction with blacklist (2 & 4) temporal effects (3 & 4).

Dependent variable:				
Value Added (BRL Billion)				
	(1)	(2)	(3)	(4)
PMV active	0.008 (0.009)	0.004 (0.009)		
PMV: year 1			−0.003 (0.006)	−0.004 (0.006)
PMV: year 2			0.004 (0.009)	0.002 (0.009)
PMV: year 3			0.004 (0.010)	−0.003 (0.010)
PMV: year 4			0.022** (0.011)	0.016 (0.011)
Blacklist active	0.021** (0.008)	0.024** (0.009)	0.022** (0.008)	0.023** (0.010)
Blacklist active * Ever in PMV		−0.029*** (0.011)		−0.029*** (0.011)
Blacklist active * Ever in PMV * PMV active		0.044* (0.022)		
Blacklist active * Ever in PMV * PMV: year 1				0.025** (0.012)
Blacklist active * Ever in PMV * PMV: year 2				0.033* (0.020)
Blacklist active * Ever in PMV * PMV: year 3				0.065** (0.031)
Blacklist active * Ever in PMV * PMV: year 4				0.063** (0.033)
Year fixed effects	Yes	Yes	Yes	Yes
Municipality fixed effects	Yes	Yes	Yes	Yes
Observations	2276	2276	2276	2276
Adjusted R2	0.887	0.888	0.887	0.889

Notes: Matched sample of nearest neighbor municipalities in the states of Mato Grosso, Pará and Rondônia. “PMV: year #” is an indicator for the #th year of membership in the PMV. Including indicator for Imazon technical assistance and interaction terms does not affect signs or statistical significance of coefficients on PMV and interaction terms. Standard errors are bootstrapped and clustered at municipality level. *p < 0.1; **p < 0.05; ***p < 0.01.

Table 4
Models of agricultural intensification including interaction with blacklist.

	Dependent variable:					
	BRL thousand/HA		Head/HA	Share of area		
	Perennial	Annual	Cattle	Perennial	Annual	Pasture
PMV active	0.013	−0.119	−2.290**	0.001	−0.001	0.012
	(0.144)	(0.107)	(1.057)	(0.001)	(0.002)	(0.007)
Blacklist active	−0.581***	0.092	0.119	−0.001**	0.014***	−0.007
	(0.164)	(0.140)	(0.785)	(0.001)	(0.003)	(0.018)
Blacklist active * Ever in PMV	0.221	−0.159	−0.596	0.001**	−0.015***	0.009
	(0.259)	(0.156)	(1.120)	(0.001)	(0.004)	(0.023)
Blacklist active * Ever in PMV * PMV active	0.038	−0.178*	2.416**	−0.0003	0.003*	0.003
	(0.240)	(0.097)	(1.018)	(0.001)	(0.002)	(0.014)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Municipality fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,636	2,643	1,158	2,636	2,640	1,158
Adjusted R2	0.837	0.728	0.668	0.790	0.929	0.943

Notes: Matched sample of nearest neighbor municipalities in the Amazon forest biome. Including indicator for Imazon technical assistance and interaction terms does not affect signs or statistical significance of coefficients on PMV and interaction terms. Standard errors are bootstrapped and clustered at municipality level. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

mies of blacklisted municipalities. That effect is robustly significant for different scopes (Amazon forest biome vs. three states) and matched samples (one vs. five nearest).

5.1.3. Possible mechanisms for economic impact of the PMV: agricultural intensification

The PMV was not designed to increase overall economic activity in municipalities but rather to put them on a sustainable economic course. To assess the plausibility of our findings that participating in the PMV increases total value added (VAF) in blacklisted municipalities, here we explore a possible mechanism: agricultural intensification to increase production without clearing more forest.

As shown in Table 4, the PMV generally did not affect our indicators of intensification. If anything, the estimation results suggest that joining the PMV reduced cattle pasture stocking in municipalities not on the blacklist. In supplemental analysis allowing temporal variation in effects (not reported here), we find significant effects in specific years but those tend to be off-setting, resulting in no net significant effect on intensification during PMV membership.

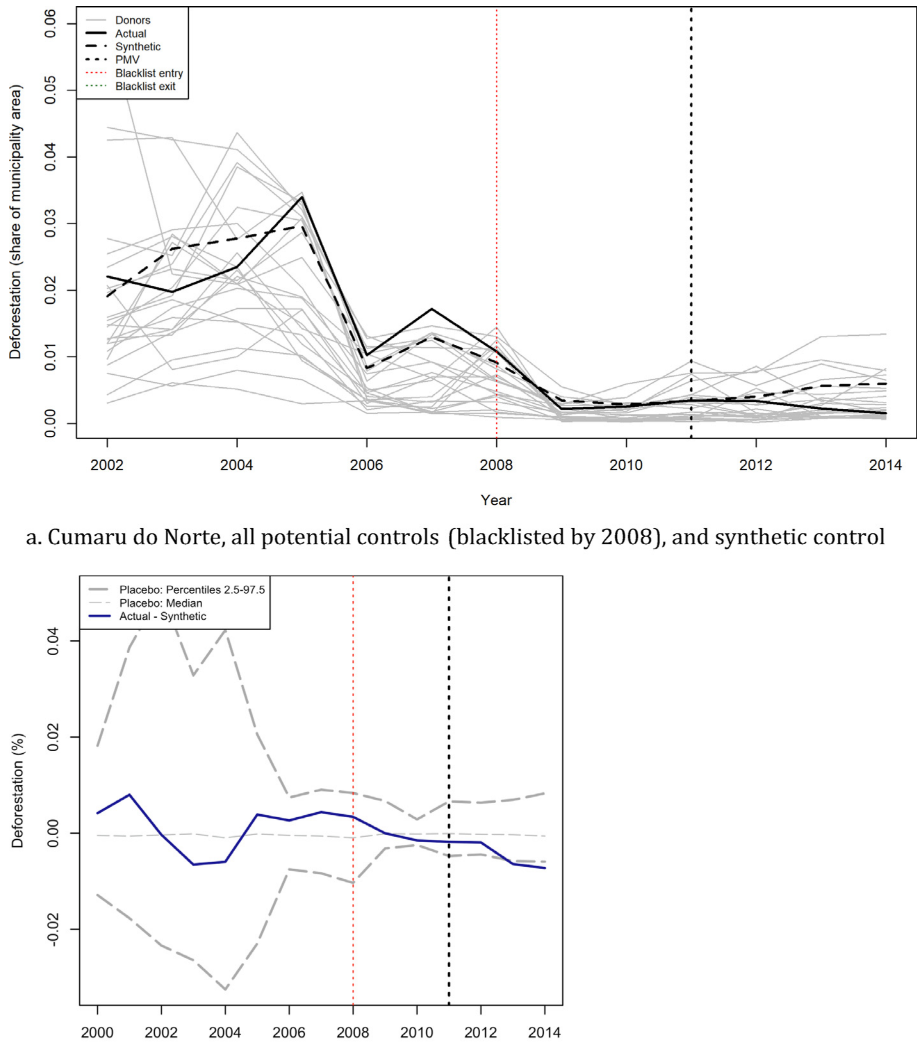
5.2. Synthetic control method

The estimated effects in Tables 2 and 3 may mask significant heterogeneity across municipalities. Further, the estimation results in Table 2 are based on a sample that does not follow parallel trends in deforestation, even though matching did generally improve the balance of observed covariates. To both improve the matching and allow for heterogeneous effects across municipalities, we construct synthetic controls for deforestation and VAF in each blacklisted municipality. This allows us to account for differences in covariates and trends across municipalities by constructing the optimal control for each, based on all years up to the time that a particular municipality signed up for the PMV. Table 5 summarizes the quality of the synthetic controls and the credible estimated effects of the PMV on deforestation and VAF. The supplemental materials

Table 5
Summary of synthetic control results for effect of the PMV on VAF and Deforestation in blacklisted municipalities.

	VAF				Deforestation			
	MSPE	Good quality SCM	Effect	Significant at 95%	MSPE	Good quality SCM	Effect	Significant at 95%
Altamira	0.00333	Yes*	Positive	2011–2014	0.000007	No	Positive	–
Anapu	0.00006	Yes	Positive	2014	0.000009	No	Flips	–
Brasil Novo	0.00032	No	Positive	–	0.000044	No	Flips	–
Cumaru do Norte	0.00018	Yes	Negative	–	0.00002	Yes	Negative	2013–2014
Dom Eliseu	0.00104	No	Positive	–	0.000039	Yes	Flips	–
Itupiranga	0.00026	Yes	Positive	–	0.000077	No	Positive	–
Marabá		**			0.000036	Yes	Positive	–
Moju	0.00003	Yes	Positive	2011–2014	0.000032	No	Positive	–
Novo Progresso	0.00069	No	Positive	–	0.000014	No	Flips	–
Novo Repartimento	0.0004	No	Positive	2012–2014	0.000105	No	Flips	2011
Pacaja	0.00007	Yes	Positive	2011–2014	0.000259	No	Flips	–
Rondon do Para	0.00093	No	Flips	2013–2014	0.000074	Yes	Negative	–
Santa Maria das Barreiras	0.0002	No	Flips	–	0.000032	Yes	Negative	–
Santana do Araguaia	0.00078	No	Positive	–	0.000017	Yes	Negative	–
Sao Felix do Xingu	0.00176	No	Positive	2012–2014	0.000012	Yes	Negative	–
Senador Jose Porifirio	0.00005	No	Flips	–	0.000002	No	Flips	–
Tailandia	0.00125	No	Negative	2011–2014	0.00002	No	Flips	–
Ulianopolis	0.00067	No	Negative	2013	0.000045	No	Negative	–

Notes: treatment effects and placebo tests for VAF based on differenced treatment effect (difference between outcome in treated vs. outcome in synthetic control, less the average difference in three years before treatment). For most municipalities, these are years when they were blacklisted but not affiliated with the PMV.
*Altamira is considered good quality despite a high MSPE, because the match is excellent in the years since blacklisting.
**Excluded because VAF is driven by largest iron ore mine in the Americas, swamping all other sources of variation and meaning that there are no Amazonian municipalities with comparable VAF.



a. Cumaru do Norte, all potential controls (blacklisted by 2008), and synthetic control

b. Treatment effect and 95% confidence interval based on placebo tests

Fig. 4. Deforestation (Percentage) in Cumaru do Norte.

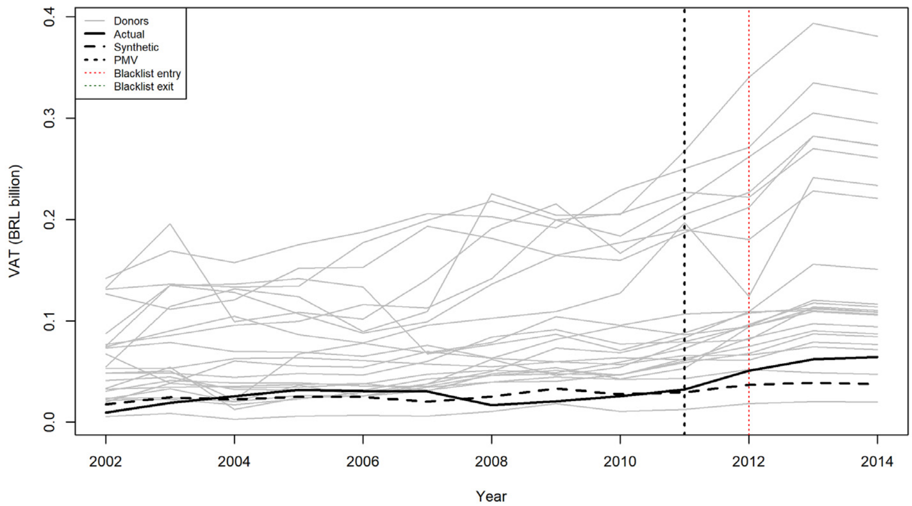
include plots of the synthetic controls and 90% and 95% confidence intervals based on the bootcebos for each blacklisted municipality in the PMV. Supplemental Table 9 presents the average size and significance of the effects as shown in the plots, for (a) all years, (b) years in which effects are significant at the 90% level, and (c) years in which effects are significant at the 95% level based on placebo tests.

5.2.1. Deforestation

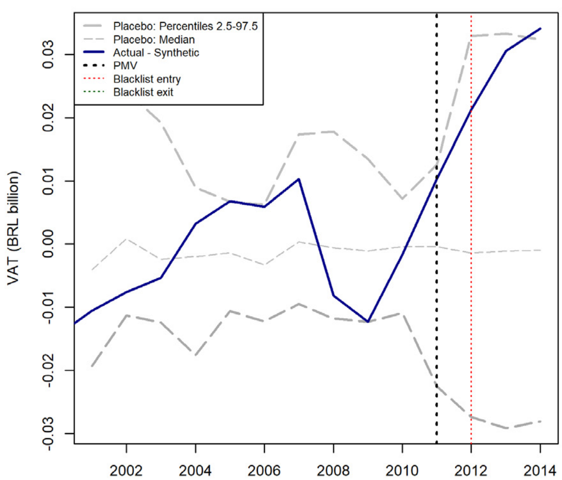
As listed in Table 5, we judge seven of the synthetic controls for deforestation to be good enough matches pre-treatment to use for estimating the effect of the PMV. In five of those cases, deforestation in the synthetic control is higher than deforestation in the municipality in the PMV, suggesting that the PMV reduced deforestation. However, this effect is only statistically significant at the 95% level in one municipality: Cumaru do Norte. Fig. 4a plots deforestation in Cumaru do Norte, its synthetic control (which has a low MSPE of 0.00002), and all blacklisted municipalities in the donor pool. Fig. 4b plots the 95% confidence interval for deforestation in Cumaru do Norte based on the bootcebos. One possible reason that the PMV is effective in Cumaru do Norte is that as one of the largest municipalities in the state, it faced greater challenges and needed more assistance to reduce deforestation below 40 km^2 in order to exit the blacklist. At the 90% confidence level, we find a significant effect in one more large municipality (Santa Maria das Barreiras) in one year (2014). Thus, overall, SCM provides very little evidence that the PMV has an additional effect on deforestation.

5.2.2. Value added

For VAF, we judge the quality of the synthetic control to be sufficient to estimate the effect of the PMV in only six blacklisted municipalities (not inconsistent with our finding of parallel trends in the panel analysis, as those trends are based on averages.) In five of the six municipalities, the estimates of PMV's impact are positive, as shown in Table 5. The results in Table 5 are based on differencing to account for any divergence in VAF in the three years before the program. However, the results hold qualitatively even without differencing (results not reported here). The effect of the PMV on VAF is statistically significant at the 95% level in at least the last year in four of those municipalities. We illustrate with one municipality (Anapú) in Fig. 5. Fig. 5a plots VAF over time, illustrating the low MSPE of 0.00006 obtained in this case. Fig. 5b shows that the size of the PMV effect grows over time, becoming significant (rising above the bootcebo confidence interval) in 2014. In sum, we find substantial evidence that affiliating with the PMV positively affects the VAF of most (but not all) blacklisted municipalities.



a. Anapú, all potential controls (blacklisted by 2008), and synthetic control



b. Treatment effect and 95% confidence interval based on placebo tests

Fig. 5. Value Added (VAF) in Anapú.

6. Conclusion

Local government officials in jurisdictions confronted with a strong collective incentive to protect forests are likely to seek to ameliorate the costs of protection, both for the sake of their budgets and for electoral reasons. In Brazil, this local objective can be represented by the valor adicionado fiscal (VAF), an indicator of the value added generated in each municipality that is used to allocate tax revenues. Given that this represents local objectives, it also becomes important for the long-run programmatic objective of enlisting local governments and stakeholders in forest protection.

After ruling out possible rival explanations using matching and fixed effects, we find that a program to increase environmental governance capacity in the Amazonian state of Pará has limited additional effects on deforestation, yet it generally does increase the VAF of municipalities participating in the program. The effect on deforestation is apparent only in one large municipality, while the effect on VAF holds across municipalities that have been targeted by the federal government for enforcement efforts and sanctions related to deforestation, i.e. municipalities immediately faced with a collective incentive to reduce deforestation. We are able to construct good quality synthetic controls for the VAF in six of those municipalities, and we confirm positive and statistically significant impacts on the VAF in four of them. This suggests that some – but not all – local governments are able to use the program to meet their objectives. We do not find any evidence that agricultural intensification, widely discussed as a way to reconcile forest conservation and economies, is the mechanism for this. Future research should focus on identifying the moderators that drive variation in this effect across municipalities and mechanisms by which the program affects local economies (Sills & Jones, 2018).

Thus, we conclude that in its first phase, the PMV did not accomplished its primary stated objective of reducing deforestation by building local environmental governance capacity. However, we suggest that its positive effects upon local economies may make efforts to conserve forests more socially and politically sustainable in the long run. As argued in the literature on polycentric approaches to decentralization, societal outcomes can be improved by strong vertical relationships between central governments, which in this case set the policy goal of forest conservation, and local governments, which in this case seek to reduce the economic costs of meeting that goal. The PMV illustrates both the limitations and the possibilities of state government efforts to build the capacity of local governments to contribute to both goals.

Conflict of interest

This research was funded by Mercy Corps under a Cooperative Agreement with USAID (AID-OAA-A-12-00044) to evaluate the Green Municipality Program, or PMV, in order to inform USAID and the Skoll Foundation about the impacts of their investments in the program.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2020.104891.

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