Green finance and deforestation reduction in Brazil: a PVAR analysis of the Amazon Fund

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Outline

Motivation:
Green finance effectiveness to fight deforestation is often controversial

▶ The Amazon Fund is the largest REDD+ fund in the world (529 USD Mn disbursed since 2009) `List of the funds`

▶ In 2019, the president of the fund stated: "Although there is clear evidence that the Amazon Fund has contributed to reducing deforestation in the Amazon rainforest, **it is a great challenge to estimate this contribution quantitatively**"

Goal:
Estimate the effectiveness of the largest REDD+ fund

How effective has the Amazon Fund been at **reducing deforestation**?

What are the most **efficient types of projects?**

Methodology

Tracking the Fund's disbursements: time and spatial distribution

- ▶ Using **web scrapping**...
- ▶ ... and the BNDES' help

Panel dataset :

- ▶ 760 municipalities of the Brazilian "Legal Amazon"
- ▶ 19 years (2002-2020)

Panel-VAR :

- ▶ Inspired from Macroeconometrics
- ▶ It enables to set a system of endogenous variables that can influence each other

Results

The Amazon Fund's action is **effective** and **efficient** (low mean abatement cost)

The efficiency (per invested BRL) **varies over the different types of projects**

- ▶ By recipient body: projects led by the **Federal Government** are more efficient than those led by states and municipalities
- ▶ By theme: **combating illegal fires** helps reduce deforestation more than the other projects
- ▶ By axis: **land use planning** is the most efficient category

Contribution of the paper and related literature

1. **Quantitative analysis of the Amazon Fund**
   - ▶ Political and organizational qualitative studies: Bidone (2021), Correa et al. (2019), Hoff, Rajão, and Leroy (2018)
   - ▶ Very few quantitative studies: Correa et al. (2020)

2. **Large scale empirical assessment of a REDD+ finance scheme**
   - ▶ In **Brazil**, Carrilho et al. (2022) or West et al. (2020)
   - ▶ Jayachandran et al. (2017) in **Uganda**, Ellis et al. (2020) in **Mexico** or Roopsind, Sohngen, and Brandt (2019) in **Guyana**

3. **Role of key factors in the amazonian deforestation**
   - ▶ Economic and financial determinants: **prices** (Assunção, Gandour, and Rocha (2015) and Silva et al. (2010)); **agricultural credit** (Assunção et al. (2020))
   - ▶ Public policies: **blacklisting municipalities** (Assunção and Rocha (2019) and Cisneros, Zhou, and Börner (2015)), **land registration** (Alix-Garcia et al. (2018)), **protected areas** (Soares-Filho et al. (2010)) and **law enforcement** (Assunção, Gandour, and Rocha (2014))
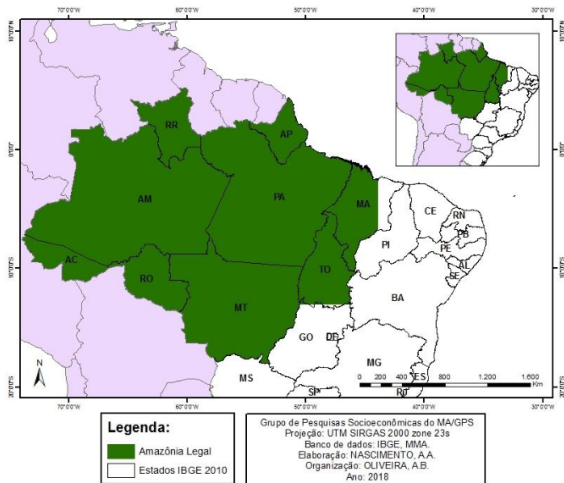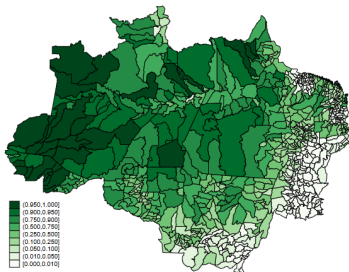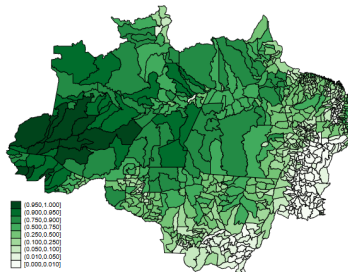
Outline

The Legal Amazon

Source: Oliveira Bezerra (2019)

Loss of forest cover: -7,4% in 18 years

Amazon rainforest density (remaining share of primary forest)


(a) in 2002

(b) in 2020

Source: INPE and authors calculations

Amazon Fund: the largest REDD+ fund in the world

Exhaustive list of REDD+ funds over the world (amounts in USD Mn)

Fund	Fund Type	Pledge	Deposit	Approval	Disbursement	Nb proj.
Amazon Fund	Multi Donor National	1288.23	1288.23	719.69	528.89	103
BioCarbon Fund ISFL	Multilateral	349.898	219.35	107	0	5
Central African Forest Initiative (CAFI)	Multi Donor Regional	478.76	319.59	182.24	182.24	11
Congo Basin Forest Fund (CBFF)	Multi Donor Regional	186.021	164.6525	83.11	58.91	37
FCPF-RF	Multilateral	466.54	466.54	311.24	253.47	46
FCPF-CF	Multilateral	874.5	874.5	0	0	0
Forest Investment Program (FIP)	Multilateral	735.86	735.86	573.73	249.18	48
UN-REDD Programme	Multilateral	329.04	323.94	323.52	315.56	35

Breakdown of REDD+ funds disbursed in Brazil since 2009

- 14%
- 5%
- 81%

- Amazon Fund
- Forest Investment Program (FIP)
- Green Climate Fund (GCF)
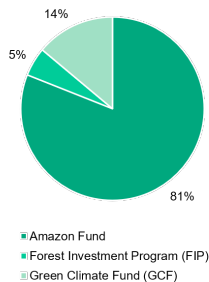
Source: Climate Funds Update (May 2022)

The Amazon Fund and green finance in Brazil

The AF in Brazil: main figures and facts

- Goal: fighting deforestation in Legal Amazon (91% of 103 projects) and other biomes
- Since its creation in 2009, 1,3 USD Bn in pledges (donations), 529 USD Mn disbursed
- Main owners: Norway Gov. (93.8%), Germany KfW (5.7%)
- Manager: Brazilian National Development Bank (BNDES)
- During Bolsonaro's government, in 2019-2022, the Fund stopped new pledges and kept on disbursements just for projects already contracted.
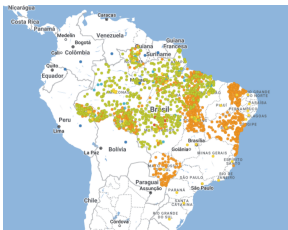
Amazon Fund projects (`www.amazonfund.gov.br`)

## Other green finance providers in Brazil: MDBs (WB, IADB, EIB, NDB)

- Larger scope of projects than the AF: energy, low carbon agriculture, sustainable infrastructures and water solutions, technical assistance, etc.
- Since 2015 MDBs disbursed 6.8 USD Bn (AF 328 USD Mn)

Categories of projects supported by the Amazon Fund

AXIS	Monitoring and control systems	42
	Science, innovation and economic instruments	25
	Land use planning	27
	Sustainable production	59
THEME	Rural Environmental Registry (CAR)	19
	Settlement	16
	Indigenous lands	28
	Conservation units	28
	Combat to illegal fires and burn-offs	6
RECIPIENT	Third Sector	58
	Federal Government	8
	States	22
	Municipalities	7
	Universities	6
	International	1

Example of project   Overlapping across categories of projects   OIRF

Huge drop of Amazon Fund disbursements since 2018

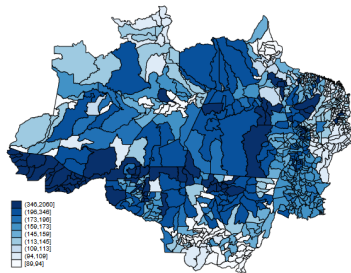Deforestation and disbursements of the Amazon Fund in the legal Amazon between 2002 and 2020
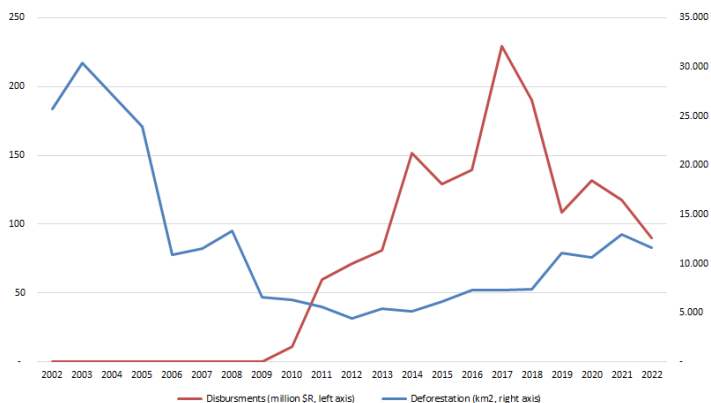
Sources: INPE for deforestation rates; BNDES and authors calculations for Amazon Fund's disbursements.

Amazon Fund disbursements are focused on the arc of deforestation
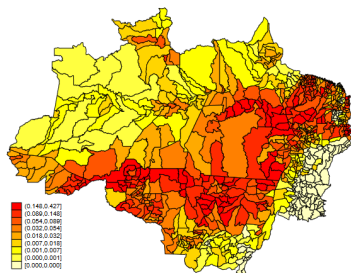
(a) Deforestation rates

(b) AF disbursements ($R\$/km^2$)

Source: INPE and authors calculations for deforestation; BNDES and authors calculations for Amazon Fund disbursements

Outline

Law enforcement: weakening in recent years

Number of IBAMA's sanctions
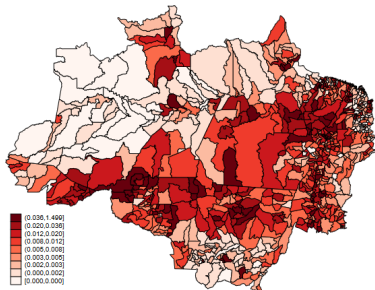
(a) Number of infractions per km^2 between 2010 and 2020
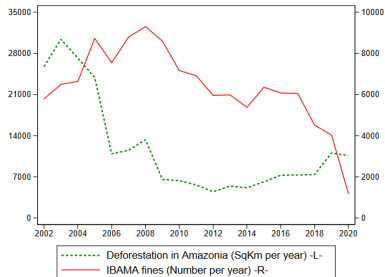
(b) Number of infractions in the legal Amazon between 2002 and 2020

Source: IBAMA and authors calculations

Disclaimer: according to the IBAMA, the data on infractions committed in 2019 and 2020 are not complete due to a change in the data collection application

Agricultural production: large rise since 2018

Growth of agricultural production between 2001 and 2020
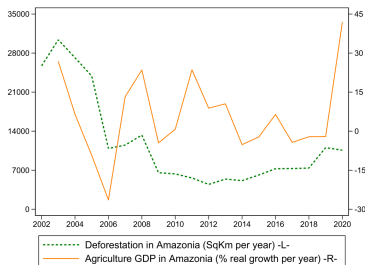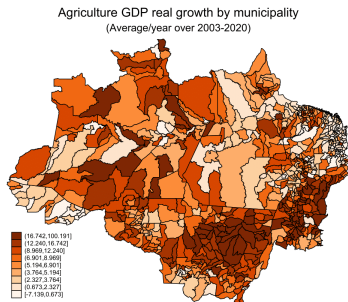
Source: IBGE and authors calculations

Agricultural production: cattle ahead of soybean

Growth of agricultural production between 2001 and 2020

(a) Steer livestock (number of heads)
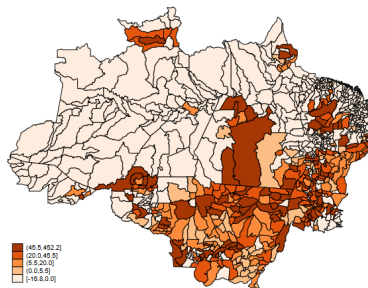
(b) Soybean production (tons)

Source: IBGE and authors calculations

Table of Contents

Panel VAR approach

System of linear equations (with p=1 lags for the benchmark case):

$$Y_{it} = \mathbf{A}_p(L)Y_{it} + \mathbf{B}X_t + f_i + e_{it}$$
$$i \in \{1, ..., 760\}$$
$$t \in \{2002, ..., 2020\}$$

Where,
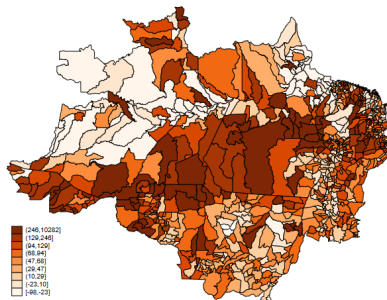
- Y_{it} is $1 \times k$ vector of endogenous variables (k=4): **Amazon Fund, Ibama, deforestation, agricultural GDP**
- X_{it} is $1 \times l$ vector of exogenous covariates (l=3): rural credit, steer price, soybean price
- f_i and e_{it} are $1 \times k$ vectors of unobserved panel specific fixed-effects and idiosyncratic errors

Estimation through GMM (Arellano and Bover, 1995)

SVAR identification scheme: policy - deforestation - agriculture

Table of Contents

Baseline results

Response: Deforestation rate (ratio/km^2)	(1)	(2)	(3)
Endogenous variables [lags]:			
Deforestation rate (ratio/km^2) [-1]	0.0299***	0.0297***	0.313***
	(3.42)	(3.34)	(7.00)
Amazon Fund disbursements (BRL/km^2) [-1]	-0.00271***	-0.00271***	-0.00130***
	(-8.11)	(-8.15)	(-4.63)
Ibama fines (BRL/km^2) [-1]		-0.00000472***	-0.00000203*
		(-3.21)	(-1.85)
Local agricultural GDP (growth) [-1]			0.000415***
			(3.73)
Exogenous variables:			
Credit to agriculture (real growth)	0.0165***	0.0165***	0.00234***
	(15.46)	(15.45)	(4.26)
Steer price (real growth)	-0.00109***	-0.00110***	0.00115***
	(-2.83)	(-2.84)	(2.83)
Soybean price (real growth)	-0.00133***	-0.00134***	-0.00195***
	(-4.58)	(-4.60)	(-9.03)
N. observations.	13680	13608	12090
N. municipalities	760	756	756

Estimation sample: 2002-2020
t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

OIRFs: the Amazon Fund and the IBAMA are effective in curbing deforestation

Response of deforestation after a 1 SD disbursement shock

Orthogonal 1 SD shocks: Response of Deforestation (% of municipality sqKm)

90% CI — Orthogonalized IRF
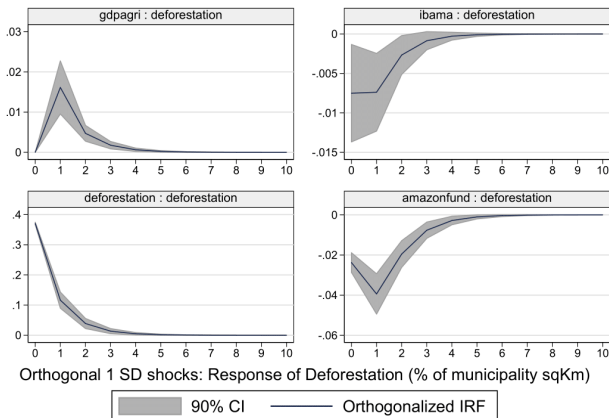
impulse : response

OIRFs: Projects led by the Federal Government are more effective than those of states and municipalities

Impact of +1BRL/Km2 of Amazon Fund disbursements on % deforestation/Km2

BY RECIPIENT

Legend: Agregate AF, Municipalities, States, Universities, Federal Gov., Third sector
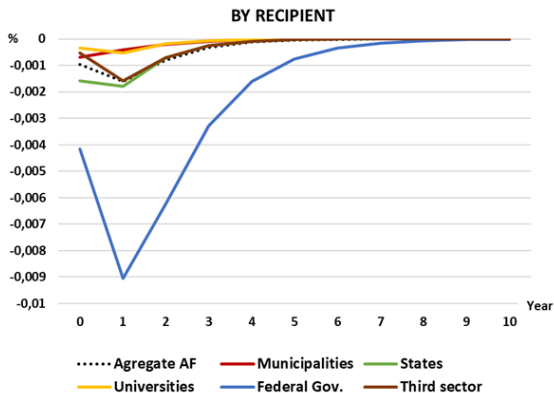
OIRFs: Land use planning projects are the most effecient

Impact of +1BRL/Km2 of Amazon Fund disbursements on % deforestation/Km2

BY PROJECT AXIS

Legend:
- ······· Agregate AF
- Monitoring and control system
- Land use planning
- Science, innovation and eco. inst.
- Sustainable production
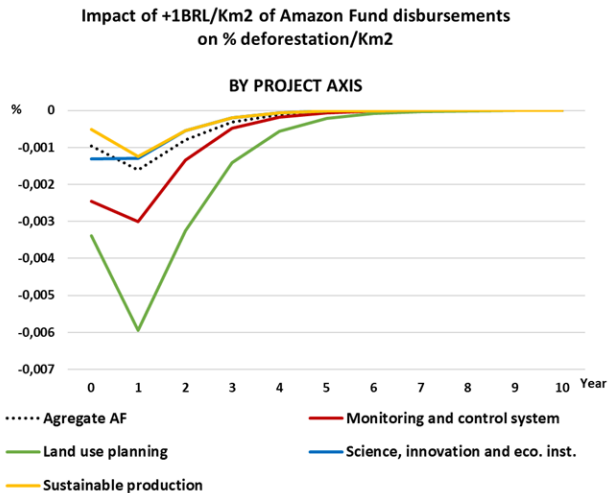
Number of projects   Overlapping across categories of projects

OIRFs: Combatting illegal fires pays off

Impact of +1BRL/Km2 of Amazon Fund disbursements on % deforestation/Km2

BY THEME

Legend:
- .... Agregate AF
- Settlement
- Conservation units
- Rural Environmental Registry
- Indigenous lands
- Combat to illegal fires
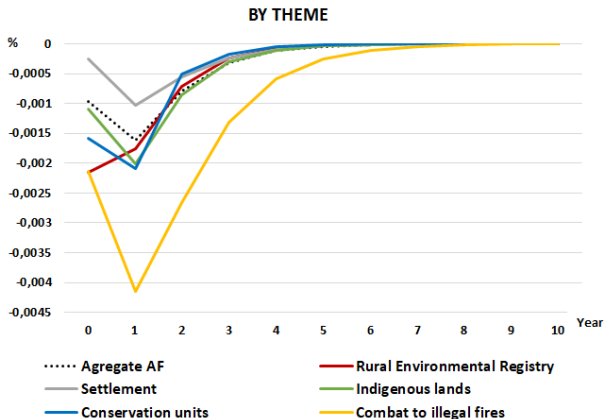
Number of projects | Overlapping across categories of projects

Estimating an abatement cost

Conventionally, clearing one hectare of primary forest releases 367 tCO_2

Estimation through counterfactual analysis `Counterfactual`

▶ Between 2009 and 2020, the Amazon Fund has disbursed **1 280 Mn** BRL in the Legal Amazon

▶ Using the GMM estimation and setting disbursements of the Fund to 0 results in a simulated increase of deforestation of **1.424 Mn** Ha between 2009 and 2020 `GMM`. This makes **523 Mn** tCO_2 saved by the Fund (ceteris paribus)

▶ This leads to an abatement cost of **2.45** BRL/tCO_2 (0.5 USD/tCO_2)

Key takeaways

▶ The Amazon Fund is **effective and efficient** : less than 1 USD makes it possible to avoid the release of 1 tCO_2.

▶ Its **impact depends on the type of project supported**. Federal Government-led projects and those aimed at combating illegal fires or protecting indigenous lands are particularly efficient.

▶ **Results robust** to other specifications: using 2 lags VAR, using cattle and soybean instead of Agri GDP, replacing exogenous macro variables by a time effect.

What's next ?

▶ Additional robustness checks: using ratios over population or over forest cover.

▶ Further research: **spillover effects** across municipalities, role of **agricultural productivity**.

Thank you !

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A theoretical approach

The constrained intertemporal maximization problem can be written as:

$$\max_{\{d_t\}_t} \sum_{t=0}^{\infty} \beta^t \left[pr D_t \left(1 - \frac{D_t}{\overline{\overline{T}}} \right) - c(1+s)d_t + R\left(\overline{d} - d_t\right) \right]$$

s.t.

$$\forall t \geq 0, d_t \geq 0$$

A theoretical approach

$$\sum_{\tau=0}^{\infty} d_\tau \sum_{q=\tau}^{\infty} \beta^q = \frac{\overline{T}}{2}\left(\frac{1}{1-\beta} - \frac{1}{pr}\left(R + \lambda_0 + c(1+s)\right)\right)$$

At the optimum, the (adjusted) discounted sum of deforestation areas are:

- an increasing function of the total stock of land $\overline{T}$ (provided β is high enough), the agricultural prices p and the intrinsic yields r;
- a decreasing function of the international donation amount per year R, and unit *production* cost of deforestation c and the stringency of law enforcement s.

A theoretical approach
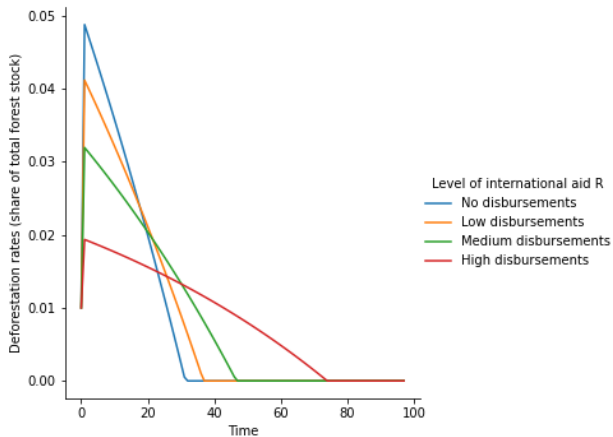
Recovering disbursements from the Amazon Fund

An example of project

Recovering disbursements from the Amazon Fund

An example

Recovering disbursements from the Amazon Fund

An example

Recovering disbursements from the Amazon Fund

An allocation process

Donors

1.3 billion US$ received in donation (93,8% from Norway)

Amazon Fund

Fund managers hosted at BNDES

Project 1

Recipient A: State of Mato Grosso

Project 2

Recipient B: WWF Brasil

Paranaíta
Area: 4 800 km^2
Forested area: 2 456 km^2
Population: 10 749

Alta Floresta
Area: 8 986 km^2
Forested area: 3 769 km^2
Population: 49 494

Carlinda
Area: 2 417 km^2
Forested area: 669 km^2
Population: 10 793

Recovering disbursements from the Amazon Fund

An allocation process
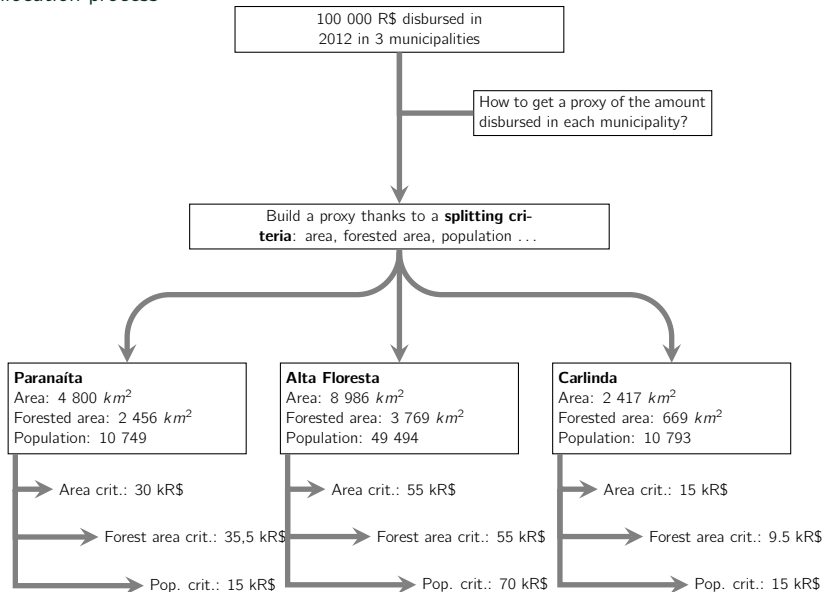
Recovering disbursements from the Amazon Fund

How focused is the fund's action across municipalities?
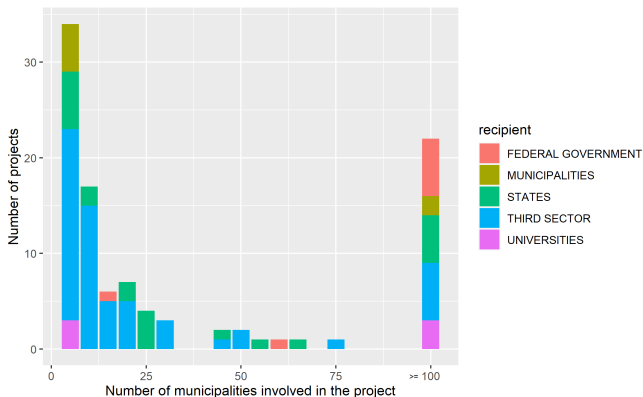
Source: BNDES and authors calculations

Main variables and data sources

- ▶ Amazon Fund disbursements: Banco National de Desenvolvimento Economico (BNDES)

- ▶ Deforestation rates: Instituto Nacional de Pesquisas Espaciais (INPE)

- ▶ Law enforcement: Instituto Brasileiro do Meio Ambiente (IBAMA)

- ▶ Agricultural production: Instituto Brasileiro de Geografia e Estatística (IBGE)

- ▶ Agricultural prices: Centro de Estudos Avançados em Economia Aplicada (CEPEA)

- ▶ Rural credit: Banco Central do Brasil (BCB)

Disbursements - Recipient
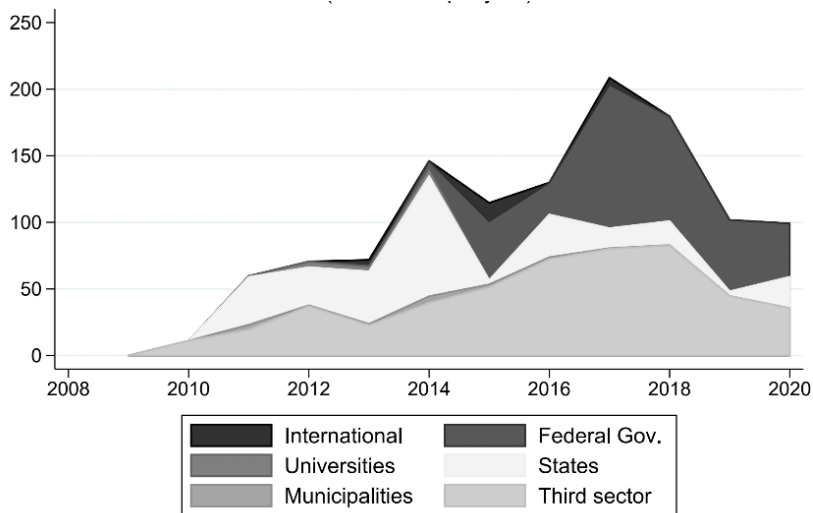
Disbursements - Axis
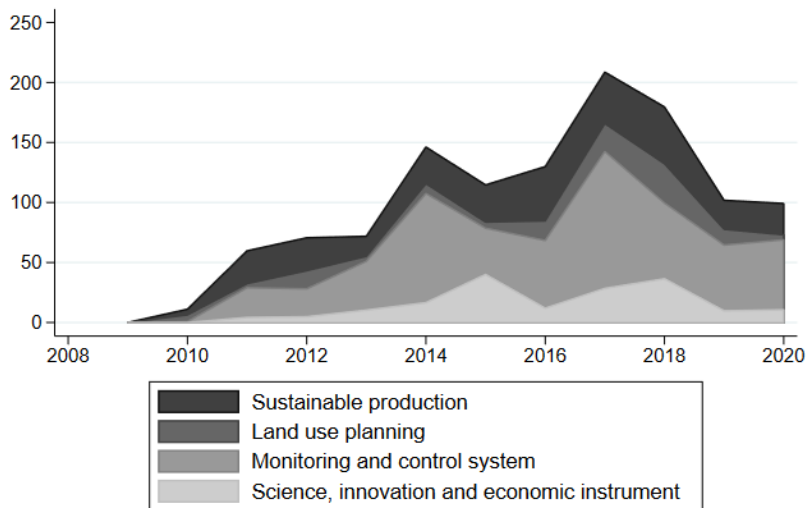
Disbursements - Theme

Overlapping matrix across categories of projects

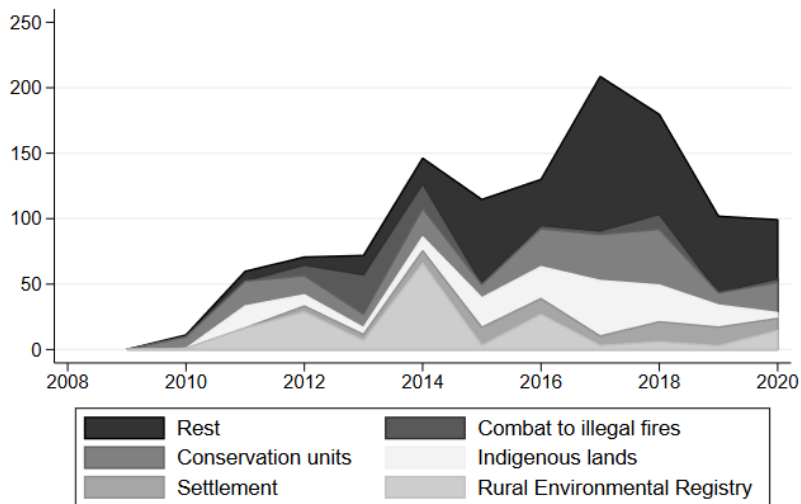|		AXIS				THEME					RECIPIENT					
		Monitoring and control systems	Science, innovation and economic instruments	Land use plann	Sustainable pro	Rural Environ	Settlement	Indigenous land	Conservation u	Combat to fire	Third Sector	Federal Govern	States	Municipalities	Universities	International
AXIS	Monitoring and control systems	100,0%	19,0%	16,7%	28,6%	45,2%	2,4%	2,4%	9,5%	14,3%	16,7%	14,3%	50,0%	16,7%	0,0%	2,4%
	Science, innovation and economic instruments	32,0%	100,0%	12,0%	40,0%	4,0%	16,0%	12,0%	32,0%	0,0%	48,0%	20,0%	4,0%	24,0%	4,0%	4,0%
	Landuse planning	25,9%	11,1%	100,0%	77,8%	7,4%	7,4%	33,6%	44,4%	0,0%	81,5%	0,0%	14,8%	3,7%	0,0%	0,0%
	Sustainable production	20,3%	16,9%	35,6%	100,0%	8,5%	27,1%	44,1%	35,6%	0,0%	84,7%	0,0%	5,1%	10,2%	0,0%	0,0%
THEME	Rural Environmental Registry (CAR)	100,0%	5,3%	10,5%	26,3%	100,0%	0,0%	0,0%	5,3%	0,0%	15,8%	0,0%	73,7%	10,5%	0,0%	0,0%
	Settlement	6,3%	25,0%	12,3%	100,0%	0,0%	100,0%	31,3%	50,0%	0,0%	100,0%	0,0%	0,0%	0,0%	0,0%	0,0%
	Indigenous lands	3,6%	10,7%	53,6%	92,9%	0,0%	17,9%	100,0%	39,3%	0,0%	92,9%	0,0%	3,6%	0,0%	3,6%	0,0%
	Conservation units	14,3%	28,6%	42,9%	75,0%	3,6%	28,6%	39,3%	100,0%	0,0%	82,1%	3,6%	10,7%	0,0%	3,6%	0,0%
	Combat to illegal fires and burn-offs	100,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	100,0%	0,0%	16,7%	83,3%	0,0%	0,0%	0,0%
RECIPIENT	Third sector	12,1%	20,7%	37,9%	86,2%	5,2%	27,6%	44,8%	39,7%	0,0%	100,0%	0,0%	0,0%	0,0%	0,0%	0,0%
	Federal Government	75,0%	62,5%	0,0%	0,0%	0,0%	0,0%	0,0%	12,5%	12,5%	0,0%	100,0%	0,0%	0,0%	0,0%	0,0%
	States	91,3%	4,3%	18,2%	13,6%	63,6%	0,0%	4,5%	13,6%	22,7%	0,0%	0,0%	100,0%	0,0%	0,0%	0,0%
	Municipalities	100,0%	0,0%	14,3%	85,7%	28,6%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	100,0%	0,0%	0,0%
	Universities	0,0%	100,0%	0,0%	0,0%	0,0%	0,0%	0,0%	16,7%	0,0%	0,0%	0,0%	0,0%	0,0%	100,0%	0,0%
	International	100,0%	100,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	100,0%

Number of projects   OIRF

All aggregate OIRFs
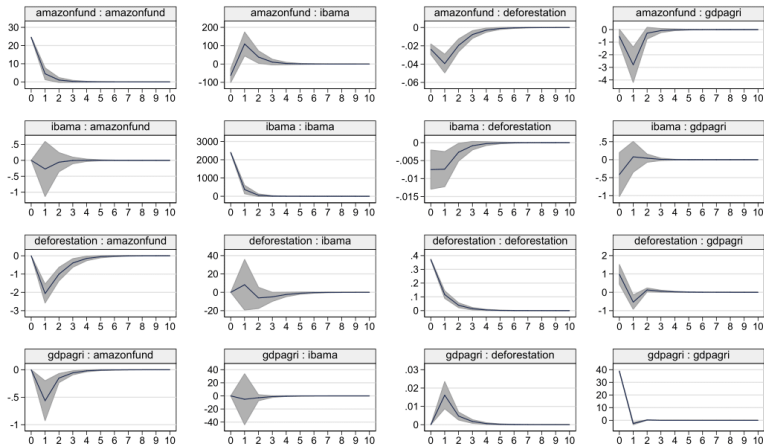
Orthogonal 1 SD shocks: Impulse (raw) and Response (column)
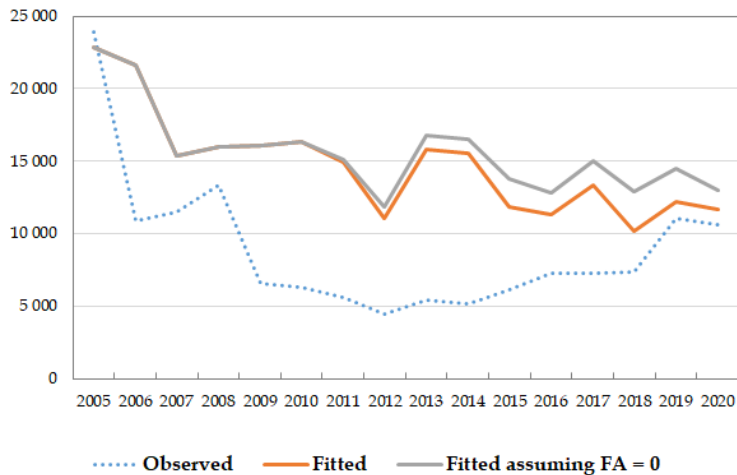
90% CI — Orthogonalized IRF

impulse : response

OIRFs for Deforestation

Counterfactual analysis

Deforestation in Legal Amazonia
(total Km²/year)

Legend: Observed (dotted), Fitted, Fitted assuming FA = 0

Estimating an abatement cost

Descriptive statistics

Variables used in estimations and main descriptive statistics of the dataset (2000-2020)

Variables	(1) N. obs	(2) Mean	(3) S.D.	(4) Min	(5) Max
Deforestation rate (% ratio/km^2 per Year)	15,960	0.451	3.137	0	97.50
Amazon Fund disbursement (BRL/km^2 per Year)	15,960	9.791	26.01	0	615.5
Ibama fines (BRL/km^2 per Year)	15,876	353.8	2,486	0	122,215
Agriculture GDP (% Y/Y real growth)	13,674	8.218	43.49	-96.34	1,805
Steer stock (heads, % Y/Y growth)	15,893	170.2	7,702	-100	720,528
Soybean production (tons, % Y/Y growth)	15,960	25.58	1,251	-100	155,803
Credit to agriculture (BRL, % Y/Y real growth)	20	5.230	8.793	-12.77	21.94
Steer price (BRL, % Y/Y real growth)	20	2.221	12.66	-15.30	33.02
Soybean price (BRL, % Y/Y real growth)	20	3.516	19.10	-30.88	44.34

Note: The table displays the transformation of variables used in our regressions. While the descriptive statistics refer to the whole available dataset, a lower number of observations are used in estimation due to lags in the VAR system

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