Berkeley Economic Review

UC Berkeley's Premier Undergraduate Economics Journal

Vol. XIV

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Abby Morris and Larry Lin
Editors-in-Chief
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Fertility Policies and Women's Education in Contemporary China: A Study of the Two-Child Policy's Effects

Monica Wu
December, 2023

Abstract

This paper examines the effects of China's 2016 Two-Child Policy, a shift from the one-child policy, with a focus on its impact on gendered educational investment. Employing a Two Way Fixed Effects (TWFE) Difference-in-Differences (DID) approach, the study assesses how this policy change influences women's educational expenditure, examining changes in spending patterns before and after its implementation while considering socioeconomic, uban-rural, and demographic factors, with an emphasis on regional differences. Through comprehensive robustness tests, including fertility age limit adjustments, Bacon Decomposition, and a placebo test, the study validates its findings. An extensive heterogeneity analysis further delineates the policy's varying effects across different ethnic and urban-rural populations. The study indicates a negative impact of the Two-Child Policy on women's educational investments, particularly affecting Han and rural women, thereby providing valuable insights for policy-making in China's evolving socio-economic landscape.

Keywords: Two-Child Policy, Women's Education Expenditure, TWFE DID

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1 Introduction

The one-child policy, introduced in China in 1979, was a landmark population control measure aimed at curbing the country's rapid population growth. Designed to limit families to a single offspring, the policy included exceptions for ethnic minorities and other select groups. However, over time, the social and economic consequences of an aging population, gender imbalances, and a shrinking workforce prompted a policy reevaluation. In response to demographic challenges, the selective two-child policy was introduced in 2013, allowing couples to have a second child if either parent was an only child, and was followed by the universal two-child policy in 2016, permitting all couples to have two children. However, both policies exempted ethnic minorities, allowing them to have more than two children to preserve cultural and demographic identity, contributing to the observed demographic heterogeneity in Section 8.2.1. The transition aimed to mitigate the adverse effects of the one-child policy, rebalance the population structure, and support China's long-term economic sustainability and social stability.

Previous literature has explored the ramifications of China's fertility regulations, particularly the one-child policy, with less focus on the more recent two-child policy. Existing research provides important perspectives, yet there is a gap in fully grasping the interplay between China's fertility policies and women's educational outcomes. While much attention has been given to the implications of the one-child policy, the subsequent two-child policy remains less studied (Jiang, 2020) [5]. Some investigations have broadly discussed shifts in women's careers after policy changes, but there is a need to delve deeper into sector-specific impacts (Ebenstein, 2010) [4]. Additionally, models and findings from non-Chinese contexts, like the U.S., may not align seamlessly with China's distinct socio-cultural milieu (Buckles, 2008) [2]. There is a need for focused research on the impact of China's two-child policy, particularly on women's educational trajectories. This study aims to examine how the policy influences educational spending among mothers with two children under 40 years old. Educational spending refers to the family's overall investment in education, primarily attributed to the mother, and includes expenses for primary, secondary, and higher education, along with costs for tutoring or vocational training. By analyzing variations in educational investments in response to the policy, this research accounts for socio-economic status, urban-rural distinctions, and demographic factors, with an emphasis on regional differences. The study also explores how ethnic minorities, benefiting from policy exceptions, may exhibit distinct investment patterns compared to the Han population. Ultimately, this research seeks to deepen our understanding of the intersection between fertility decisions and women's educational opportunities, considering the influence of gendered household responsibilities.

The methodology section of this study employs a two-way fixed effects Difference-in-Differences (DID) strategy to assess the causal link between China's two-child policy and women's educational expenditure. This approach contrasts women impacted by the selective/universal two-child policy (treatment group) with those unaffected (control group), controlling for unobserved heterogeneity. Key elements of the methodology include a parallel trend analysis of the average per log of education expense from 2012 to 2020, robustness checks incorporating fertility age limits and Bacon Decomposition, and a placebo test to ensure the reliability of findings. Additionally, the study conducts a heterogeneity analysis to examine the differential effects of the two-child policy across various demographic groups, with particular focus on ethnic disparities between Han and minority populations. Ethnic minorities have benefited from policy exemptions, allowing them to have more than two children, a measure aimed at supporting population growth and preserving cultural identities. Additionally, the study explores the contrast between urban and rural settings, recognizing that the uneven application of the policy has contributed to demographic heterogeneity in fertility rates and educational investment. By addressing these factors, the research aims to provide a nuanced understanding of how the two-child policy has influenced educational spending among women in China.

This study offers a comprehensive exploration of how the shift from China's one-child policy to the Two-Child Policy has affected mothers' education. By employing the Difference-in-Differences approach, it analyzes educational trends before and after the policy's enactment, accounting for variables like socio-economic status, urban or rural residence, and personal demographics. The primary objective is to discern the specific impacts of the Two-Child Policy on mothers' educational levels. This research employs TWFE DID to examining the Two-Child Policy, addressing endogeneity and other key factors.

2 Literature Review

The academic literature on China's shift from the One-Child Policy to the Two-Child Policy presents an extensive analysis of its impact on family dynamics, women's roles, and educational outcomes. This body of work is divided into several key thematic areas, each offering distinct insights into the socio-economic implications of this policy change. Studies such as Ebenstein (2010) [4] provide essential context on the gender imbalances caused by the One-Child Policy, but they often lack a detailed examination of the long-term socioeconomic effects, particularly in labor markets and aging populations. Similarly, works by Xu Pak (2015) [8] and Parker (2015) delve into demographic shifts and women's higher education participation, yet they could be enriched by qualitative research capturing personal narratives and community impacts.

Angrist and Evans (1996) [1] contribute to this discourse by examining the impact of family size on parents' labor supply. Their research offers critical insights into how variations in family size can influence labor market participation, particularly among women. However, this study could be further enriched by exploring the specific socio-cultural contexts that shape these labor supply decisions in the backdrop of changing demographic policies. In the realm of educational attainment and economic outcomes, Jiang (2020) [5] offers a contemporary analysis of the immediate effects of the Two-Child Policy on women's education in China. However, this study is limited by its lack of a longitudinal perspective, which is crucial for understanding long-term educational and career trajectories of women under this policy. Intra-household dynamics and resource allocation, as explored by Butcher and Case (1994) [3] and Jia, Zhou, Yang (2021) [10], provide insights into decisions regarding sibling sex composition and the "Selective Two-Child" Policy. Yet, these studies might not fully capture the evolution of these dynamics amidst modern economic and societal changes, especially in urban settings. Wu (2022) [7] provides a comprehensive analysis of fertility and maternal labor supply in urban China, highlighting the significant regional variations in the impact of the Two-Child Policy. The work of Buckles (2008) [2] delves into the economic returns and challenges associated with delayed childbearing for working women. This study is significant for understanding how family planning decisions, influenced by policies like the Two-Child Policy, can affect women's career trajectories and economic independence. However, it primarily focuses on economic aspects and might benefit from a broader socioculturalanalysis, especiallyinthecontextofChina'suniquedemographicenvironment. Qian (2008) [6] provides a nuanced economic analysis of gender imbalances in China, linking them to sex-specific earnings. This perspective is vital for understanding the economic underpinnings of demographic shifts induced by family planning policies. Yet, the study's scope could be expanded to include more comprehensive cultural and policy-driven factors that influence gender imbalances in the context of China's Two-Child Policy.

This paper distinguishes itself by focusing on the impact of the Two-Child Policy on women's educational outcomes and introducing a novel variable for measuring women's education, contributing uniquely to the existing literature. Building on these foundational works, my research provides a focused analysis of the policy's effect on women's educational expenditure, utilizing unique China Family Panel Studies datasets from 2012 to 2020 and robust methodologies. By exploring new dimensions of the policy's long-term effects, particularly regarding women's empowerment and economic participation, this research aims to fill gaps in the current literature, offering a more granular understanding of the policy's impact at both the individual and community levels, thus enriching the discourse on China's demographic and policy shifts.

3 Data

3.1 Data Source

This study utilizes the rich demographic and fertility data from the China Family Panel Studies (CFPS), which employs a multi-stage, stratified random sampling method to ensure a nationally representative sample. The CFPS covers households across 25 provinces, including both urban and rural areas, representing approximately 80 percent of China's population. By balancing key demographic groups and accounting for rural-urban and regional disparities, the dataset provides a robust foundation for examining the educational impacts of China's Two-Child Policy on mothers using a Difference-in-Differences (DiD) methodology. By categorizing mothers from early-adopting cities as the treatment group and those from later-adopting cities as the control group, we are able to isolate and analyze the policy's impact, drawing clear inferences about its influence on educational levels. The comprehensive data provided by CFPS ensures a thorough and nuanced understanding of the policy's effects, making it a vital asset for our investigation into the educational outcomes of women under China's fertility policies.

3.1.1 Table 1: Summary Statistics

Table 1: Summary Statistics for the Main Variables

Variable name	Obs	Mean	Standard Deviation	Min	Max	Median
Log of Educational Fees	31741	0.0333	0.5268	0	10.5967	0
DID Estimator	31741	0.1541	0.3610	0	1	0
Log of Family Scale	31741	1.4254	0.3862	0	2.3026	1.3863
Log of Per Capita Net Family Income	31741	8.9654	1.1658	4.9618	11.2730	9.1226
Net Family Assets	31741	349488.4	620604.6	-109749	4325800	160426
Log of Age	31741	3.6699	0.2232	3.1355	4.0431	3.7136
Native Status	31741	0.9109	0.2849	0	1	1
Health Status	31741	2.7786	1.2488	1	5	3
Urban Residency Indicator	31741	0.4485	0.4974	0	1	0

The summary statistics post-two-child policy indicate an average educational fee investment (Mean: 0.0333, SD: 0.5268), reflecting diverse educational spending. The DID estimator shows a modest average impact of the policy (Mean: 0.1541), with a binary distribution (Max: 1). Financial variables such as family scale (Median: 1.3863, Min: 0) and income (Median: 9.1226) suggest economic disparities, with income generally higher and family scale tending to be lower. Net family assets (Mean: 349488.4, SD: 620604.6) have a broad range, indicating wealth concentration among some families. Age distribution appears relatively uniform (Mean: 3.6699), with most of the sample being urban natives (Nat: 0.9109, Urb: 0.4485) and reporting good health (Mean: 2.7786), factors that may correlate with educational investment levels. Median values provide a balanced view against the presence of outliers.

3.2 Methodology

In the study, a two-way fixed effects Difference-in-Differences (DID) methodology is used to evaluate the causal influence of China's transition from a one-child to a two-child policy on educational expenditures for women. The DID approach serves as a robust econometric technique to discern the effects of policy interventions. By comparing temporal changes in educational investments between a treatment group, those impacted by the policy change, and a control group, not subject to the policy, the analysis aims to isolate the policy's net effect. This comparative framework is essential for mitigating potential biases arising from unobserved confounding variables, thereby facilitating a more accurate estimation of the causal relationship between the two-child policy and women's education expenditure.

3.2.1 Econometric Model

$$log(Education\_fee_{it}) = \alpha_0 + \alpha_1 DID_{it} + \alpha_2 Treat_i + \gamma X_{it} + \delta_{t,year} + \varepsilon_{it}$$

4 Econometric Model

In the econometric model, the dependent variable ln($Education\_fee_{it}$) represents the educational investment in response to the two-child policy for women i in year t. $Treat_i$ strictly denotes whether individual i meets the eligibility criteria for the two-child policy. The interaction term $Treat_i \times Post_{it}$ is used to determine the effect of the policy on educational spending, with Postit indicating the post-implementation period of the policy. The model includes control variables X_{it}, which encompass demographic and economic factors to mitigate potential confounding effects. Individual fixed effects $\lambda_{i,pid}$ are introduced to control for individual-specific attributes that do not vary over time, while year fixed effects $\lambda_{t,year}$ are included to adjust for yearly changes. The error term εit captures the deviations of the predicted values from the observed values of educational investment.

Note: DID_{it} represents the interaction term $Treat_i \times Post_{it}$.

4.1 Analytical Approach

The DID method allows us to dissect the before-and-after effects of the policy implementation, offering a nuanced understanding of how the two-child policy has reshaped educational investments among affected women. By accounting for individual characteristics and broader temporal trends, the model ensures that the derived conclusions about the policy's influence are not conflated with extraneous factors. This study is committed to unveiling detailed insights into the policy's ramifications on educational spending, aiming to enrich the discourse on fertility policies and their societal impacts.

5 Results

Table 2: Regression of the Two-Child Policy on Female Educational Expenditure

	(1) lnedu_fee	(2) lnedu_fee	(3) lnedu_fee	(4) lnedu_fee	(5) lnedu_fee	(6) lnedu_fee
DID Estimator	-0.028**	-0.049***	-0.046***	-0.062***	-0.048***	-0.062***
	(-2.25)	(-3.08)	(-3.42)	(-3.52)	(-3.63)	(-3.58)
Treat	0.077***		0.050***		0.035***	
	(7.52)		(5.31)		(3.59)	
Log of Age			-0.156***	0.443	-0.188***	0.463
			(-7.49)	(1.48)	(-7.68)	(1.54)
Nationality Status			-0.011	0.008	-0.018	0.006
			(-0.99)	(0.35)	(-1.61)	(0.27)
Health Status			0.003	0.004	0.004*	0.004
			(1.57)	(1.25)	(1.77)	(1.21)
Urban Residency Indicator			0.035***	-0.014	0.020***	-0.016
			(5.65)	(-0.85)	(3.48)	(-0.96)
Log of Family Scale					-0.031***	-0.033**
					(-3.05)	(-2.07)
Log of Per Capita Net Family Income					0.011***	-0.002
					(4.14)	(-0.77)
Net Family Assets					0.000***	0.000
					(3.29)	(0.87)
Constant	0.011***	0.039***	0.581***	-1.597	0.649***	-1.607
	(5.05)	(9.79)	(7.47)	(-1.45)	(6.50)	(-1.46)
Year_FE	Yes	Yes	Yes	Yes	Yes	Yes
Women_FE	No	Yes	No	Yes	No	Yes
N	31741	30335	31741	30335	31741	30335
F	34.263	9.465	17.447	2.788	11.870	2.394
r2_a	0.006	0.154	0.009	0.154	0.012	0.154

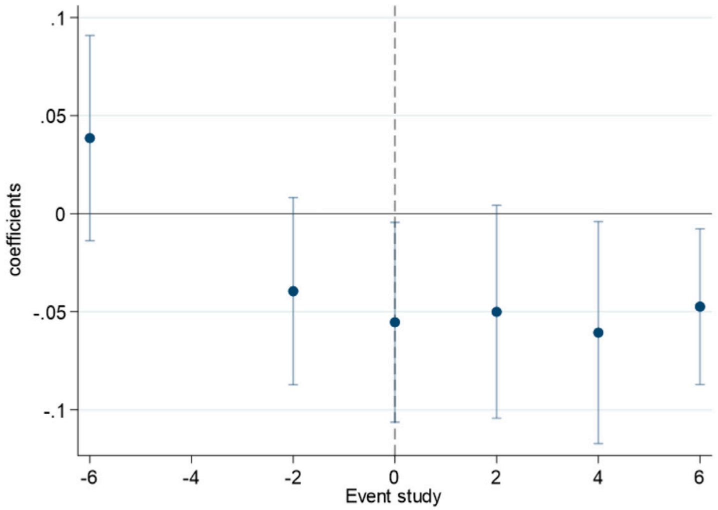
Note: This table presents regression results on the impact of the Two-Child Policy on female educational expenditure. DID_{it} represents the interaction term $Treat_i \times Post_{it}$. The variable $Treat$ indicates treatment group membership. Columns (1)-(6) progressively control for confounding factors: odd columns (1, 3, 5) adjust for treatment-control group differences, while even columns (2, 4, 6) further control for women-specific heterogeneity with fixed effects. Early columns (1, 2) have no controls, mid columns (3, 4) control for individual attributes (age, health), and later columns (5, 6) include family-level factors (income, assets). $Year\_FE$ and $Women\_FE$ represent fixed effects for year and women, respectively, with N totaling 31,741 observations. F-statistics and adjusted R-squared values are denoted by F and $r2\_a$. Standard errors are in parentheses, with significance marked by * ($p < 0.1$), ** ($p < 0.05$), *** ($p < 0.01$).

The regression analys is employing a Difference-in-Differences(DID) approach discerns the nuanced effects of the Two-Child Policy on Female Educational Expenditure, highlighting a dual nature of impact. The DID estimator unveils a negative correlation, with coefficients between -0.028 and -0.062 signifying a policy-driven dip in educational spending for females. Conversely, the treatment variable evidences a positive influence, with increments ranging from 0.035 to 0.077 in educational expenditure for those under the policy's purview, most notably with a significant boost at the 0.1 percent level in model (1). This juxtaposition suggests an intricate interplay of policy implications, where direct policy effects contrast with individual responses. Additionally, variables such as age, urban residency, and family scale provide a spectrum of influences, further complicating the interpretation of educational investment behaviors.

The robustness and explanatory power of the models are supported by high F-statistics, such as 34.263 in model (1), demonstrating the joint significance of the variables. Additionally, adjusted R-squared values around 0.154 in several models indicate the proportion of variance in educational expenditure explained by the predictors. Notably, the positive constants across models ensure a non-null baseline for educational spending. These results collectively depict a scenario where, despite a general policy-induced reduction in educational spending for females, those within the treatment group exhibit an anomalous increment, necessitating a layered analysis of the policy's differential effects across demographic strata.

6 Parallel Trend

Figure 1: Average Per Log of Education Expense in 2010 to 2020



The parallel trend examines the impact of the Two-Child Policy on education expenditures by comparing treatment and control groups. Treatment groups consist of women affected by either the selective or universal Two-Child Policy, implemented in different years across provinces, while the control group consists of women not impacted by either policy. The dataset spans from 2010 to 2020, with a year range from -6 to 6 relative to the policy start year. The even-numbered periods (-6, -4, -2, 0, 2, 4, 6) are chosen to capture both pre- and post-policy effects. In provinces with the selective policy, '0' corresponds to 2014, '-2' to 2012, and '2' to 2016; for provinces with the universal policy, '0' corresponds to 2016, '-2' to 2014, and '2' to 2018. The policy, which allows families to have a second child, is expected to influence education expenditures, and the trend analysis reflects changes before and after its implementation, providing insight into the policy's effects over time.

The study expands its analysis beyond the scope of the second-child policy, which serves as its focal point, by considering the potential impact of prior relaxations in birth control regulations and educational initiatives on women's education. Notably, before 2011, several provinces progressively relaxed the birth restrictions on families where both parents were only children, coinciding with a proliferation in the construction of girls' schools across various levels. Such pre-policy exogenous shocks have the potential to induce variations in the educational investments among women, whether they were the target of the second-child policy or not. This raises concerns about possible overestimation or underestimation in the coefficient estimations.

The integrity of the parallel trends assumption was rigorously tested over the periods [-2,2]. The resulting analysis, depicted in the figure above, reveals that coefficients for the two periods preceding the policy implementation are positive but do not meet the 5 percent level of statistical significance. This outcome suggests that there is an absence of pre-existing trends, thereby confirming that the educational trajectories for women in both the treatment and control groups were indeed parallel prior to policy implementation.

To further substantiate this finding, the study also examined the average education expenses for women from period -6 to period 6. This examination revealed that the average education expenses for the treatment and control groups followed a similar trajectory prior to the policy's enactment. Such consistency reinforces the assumption that the sample satisfies the pre-trend condition, lending credibility to the parallel trends analysis within the context of this policy evaluation.

7 Robustness Checks

7.1 Bacon Decomposition

Table 3: Bacon Decomposition

Type	Beta	Total Weight
Early_v_Late	0.0817	0.0170
Late_v_Early	-0.0267	0.0255
Never_v_timing	-0.0407	0.9575

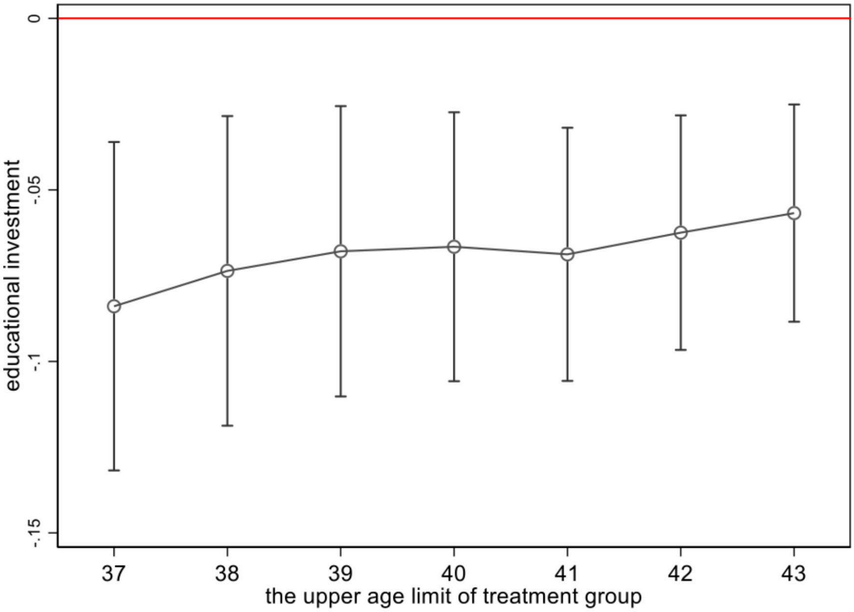
This paper uses TWFE (Two-Way Fixed Effects) to estimate the exogenous shock effects of staggered difference-in-differences. Although it can control non-time-varying individual heterogeneity more clearly and effectively, the average treatment effect of TWFE-DID is essentially a convex weighted average of the classical 2×2 DID (Difference-in-Differences) estimator. This involves cases where samples that received treatment earlier (the individual two-child policy group) serve as the control group for those who received treatment later (the universal two-child policy group), leading to the presence of substantial negative weights in the average treatment effect. If the proportion of negative weights is too high, it could result in TWFE estimates that are completely opposite to the actual policy effects. We will use the Bacon decomposition method to diagnose the proportion of negative weights (Goodman-Bacon, 2021), and the results can be seen in the table above. The share of Late_v_Early in the total weight is only about 2.55%, which indicates that the two-way fixed effects can yield consistent estimation results.

7.2 Robustness Test

In conducting a robustness check of the impact of fertility age limits on the study of the two-child policy and female educational investment, it is crucial to acknowledge that the age of 40 is not a definitive natural breakpoint for a woman's fertility. Research [7] indicates that the likelihood of childbirth diminishes progressively with age and is intricately linked to a woman's health status. Setting an artificial upper age limit for fertility can inadvertently include women under 40 with weaker fertility in the treatment group, thereby introducing a potential sample selection bias.

To address this concern, the robustness test involves adjusting the upper age limit of fertility for the treatment group to several thresholds: 37, 38, 39, 41, 42, and 43 years of age. By conducting regression analyses for each of these revised upper limits, we aim to minimize the discrepancy between the treatment group and the actual population of women capable of childbearing. This approach is expected to attenuate the selection bias associated with the inclusion of less fertile women and amplify the discernibility of the policy's net effect.

Figure 2: Robustness Test: Adjusting the Upper Age Limit for Female Fertility.

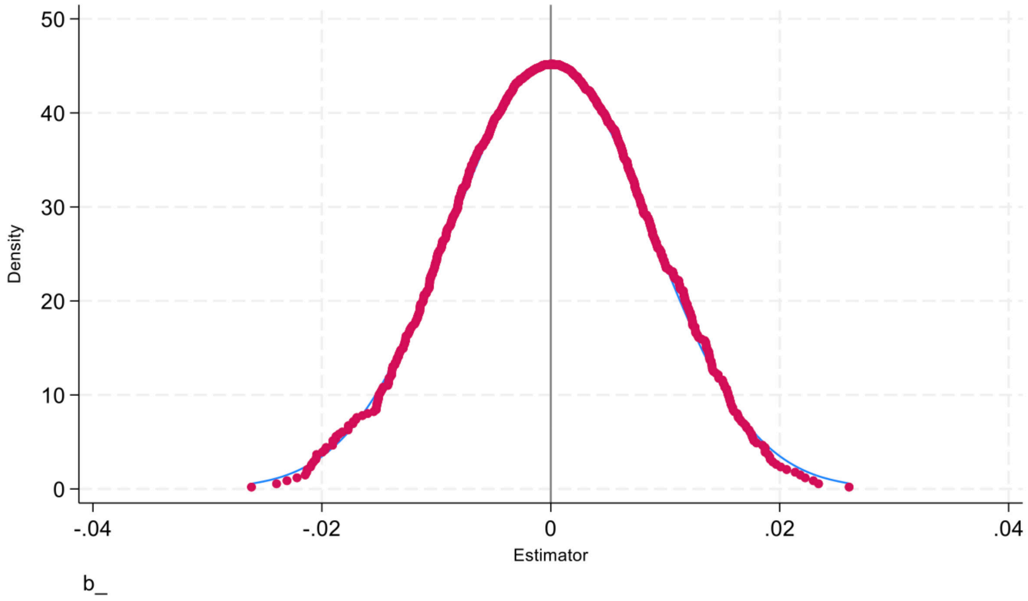


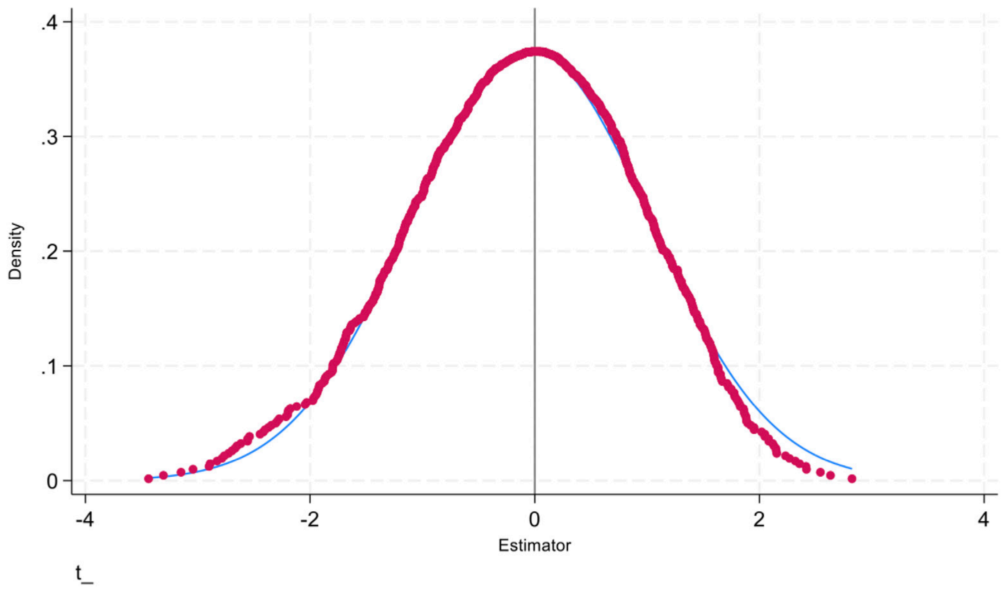
The regression outcomes demonstrate that a lower set upper age limit correlates with a higher congruence between the treatment group and women who are genuinely fertile. The findings consistently reveal that, regardless of the age limit set, the policy interaction term, denoted as the 'did' coefficient, is significantly negative. Crucially, this coefficient's confidence interval narrows as the upper age limit decreases, aligning with the hypothesis that a more precise age limit could reduce selection bias.

This pattern validates the hypothesis that a lower fertility age ceiling yields a treatment group more representative of the actual fertile population, thereby clarifying the policy's net effect. The narrowing confidence intervals corroborate the anticipated outcomes and further attest to the two-child policy's suppressive impact on women's educational investments. This robustness check substantiates the initial findings and strengthens the argument that policy design must consider the nuanced variations in fertility across different age groups to accurately assess its influence on educational outcomes.

8 Further Discussion

8.1 Placebo Test





In assessing the impact of the two-child policy on female educational investment, a placebo test was conducted to ensure the robustness of our regression results against potential biases from unobserved individual and family characteristics. By constructing 1000 placebo policy variables and integrating them into the regression model, we observed the resulting coefficients' distribution.

Contrary to expectations of significant deviations if unobservable factors were influencing policy classification and educational investment, the placebo coefficients were symmetrically distributed around zero. The mean of these coefficients was approximately 2.27 × 10−5, a negligible fraction of the true coefficient's absolute value, with the majority of T-statistics remaining below the 5% significance level threshold.

This distribution pattern led us to reject the hypothesis of bias from unobserved factors, affirming the robustness of our baseline regression estimates. The placebo test's findings thus validate the integrity of our empirical approach, supporting the reliability of the observed policy effects on educational investment.

8.2 Heterogeneity

8.2.1 Heterogeneity Test: Han vs. Minority

	(1) Han	(2) Han	(3) Minority	(4) Minority
DID Estimator	-0.055***	-0.055***	-0.095	-0.097
	(-3.05)	(-3.11)	(-1.30)	(-1.32)
Log of Age	0.117	0.140	3.376**	3.344**
	(0.39)	(0.47)	(2.58)	(2.54)
Health Status	0.002	0.001	0.023**	0.024***
	(0.48)	(0.44)	(2.58)	(2.64)
Urban Residency Indicator	-0.001	-0.003	-0.191	-0.192
	(-0.07)	(-0.18)	(-1.45)	(-1.48)
Log of Family Scale		-0.032**		-0.029
		(-2.03)		(-0.35)
Log of Per Capita Net Family Income		-0.002		-0.008
		(-0.63)		(-0.75)
Net Family Assets		0.000		0.000
		(0.69)		(0.39)
Constant	-0.394	-0.421	-12.252**	-12.027**
	(-0.36)	(-0.38)	(-2.57)	(-2.52)
Year_FE	Yes	Yes	Yes	Yes
Women_FE	Yes	Yes	Yes	Yes
N	27669	27669	2661	2661
F	2.652	2.229	2.386	1.467
r_a^2	0.167	0.167	0.061	0.061

Notes: Odd columns include individual characteristics; even columns add family characteristics. *** p<0.01, ** p<0.05, * p<0.1

Geographical and political particularities have historically led to a leniency in birth control policies within ethnic minority regions, potentially attenuating the two-child policy's efficacy. This study investigates the differential impact of this policy on women's education across ethnic lines by segmenting the data into Han and ethnic minority subsets for separate regression analyses. Findings delineated in the subsequent table reveal a pronounced inhibitory effect on education primarily among Han women, where policy interaction term coefficients are significantly negative at the 1 percent significance level in columns (1) and (2). Conversely, the policy appears to exert no substantial effect on ethnic minority women, as evidenced by the interaction terms in columns (3) and (4), which do not achieve statistical significance at the 10 percent level. These results are in alignment with the hypothesized outcomes predicated on ethnic variations in policy impact.

8.2.2 Heterogeneity Test: Urban vs. Rural

Table 5: Heterogeneity of Two-Child Policy on Education by Location

	(1) Urban	(2) Urban	(3) Rural	(4) Rural
DID Estimator	-0.043	-0.045	-0.048***	-0.047***
	(-1.48)	(-1.55)	(-2.61)	(-2.61)
Log of Age	-0.416	-0.369	0.645*	0.665**
	(-0.65)	(-0.57)	(1.96)	(2.02)
Nationality Status	-0.021	-0.025	0.012	0.006
	(-0.31)	(-0.33)	(1.40)	(0.41)
Health Status	0.005	0.005	0.002	0.001
	(0.71)	(0.71)	(0.77)	(0.70)
Log of Family Scale		-0.051		-0.035*
		(-1.61)		(-1.92)
Log of Per Capita Net Family Income		-0.003		-0.001
		(-0.48)		(-0.16)
Net Family Assets	0.000	0.000	0.000	0.000
	(1.22)	(0.40)	(1.22)	(0.40)
Constant	1.599	1.513	-2.365*	-2.379**
	(0.68)	(0.63)	(-1.95)	(-1.97)
Year_FE	Yes	Yes	Yes	Yes
Women_FE	Yes	Yes	Yes	Yes
N	13268	13268	16406	16406
F	1.249	1.586	1.922	1.483
r_a^2	0.149	0.149	0.213	0.213

Notes: Odd columns control for individual characteristics; even columns include family characteristics. *** p<0.01, ** p<0.05, * p<0.1

The impact of China's two-child policy on women's education appears to be influenced by sociocultural factors, particularly in rural areas where pro-natalist attitudes, such as the belief that "more children bring more fortune," are more common. The financial and time burdens associated with raising additional children may diminish the perceived value of investing in women's education, reinforcing traditional gender roles. Additionally, limited educational and career opportunities in rural regions, coupled with cultural norms that prioritize women's roles as caregivers, likely contribute to the stronger deterrent effect observed in these areas. This is evidenced by significant negative coefficients in rural female samples versus statistically weaker results for urban females. The study also identifies an underexplored causal factor: the role of social networks in shaping fertility decisions and educational outcomes. Although the rise in fertility discussions across various social spheres from 2015 to 2017 suggests a possible shift in women's reproductive intentions, limitations in the China Family Panel Studies dataset restrict a comprehensive analysis of these effects.

8.3 Interpretation

The transition from a one-child policy to a two-child policy in China was a strategic response to demographic challenges such as an aging population and gender imbalances caused by the initial policy. This policy aimed to control rapid population growth but resulted in issues like a declining workforce and an aging demographic [9]. The two-child policy was introduced to address these concerns, allowing families to have an additional child in hopes of revitalizing the population structure and correcting gender ratios.

This contrast likely reflects the additional financial and time burdens of raising a second child, which may lead to shifts in family budget priorities. The varying effects between Han women and ethnic minorities can be attributed to the differences in the strictness and timing of the policy's implementation across regions. The focus on women's educational outcomes is justified, as women typically bear primary responsibility for child-rearing and educational decisions. Moreover, women often face greater career inequality and, following childbirth, maybe more likely to reduce or leave their employment, further influencing financial decisions within the household. In the following sections, the study will distinguish between possible causal mechanisms underlying the results and their direct interpretation.

The Difference-in-Differences analysis of China's Two-Child Policy reveals a complex impact on women's educational spending. On average, the policy resulted in a 2.8% to 6.2% reduction in educational expenses, with coefficients ranging from -0.028 to -0.062. However, within the treatment group, educational expenditures increased by 3.5% to 7.7%, as indicated by coefficients ranging from 0.035 to 0.077. The contrast in educational spending is likely driven by the increased financial and time burdens of raising a second child, which shift family budget priorities. Women play a central role in managing household finances and making educational decisions, especially in societies where gender roles assign them primary responsibility for children's education. While the broader family budget is affected by the costs of raising a second child, women often have a more direct influence on educational spending. Han women in urbanized areas face greater challenges in balancing work and family, leading to reduced educational investments, while ethnic minorities, influenced by distinct cultural norms, respond differently. Furthermore, women's career inequality, where they are more likely to reduce or leave their employment after having children, reinforces their central role in educational decisions. Focusing on women's educational outcomes offers key insights into how changes in family finances disproportionately affect their access to educational resources, highlighting the gendered nature of financial decision-making within households. Additionally, the policy's impact differs between urban and rural areas, likely owing to divergent socio-economic conditions, such as higher living costs and educational aspirations in urban areas, versus the potential support systems and lower educational costs in rural settings, illustrating the nuanced socio-economic and demographic influences of the Two-Child Policy across China.

However, this policy shift has led to reduced investment in women's education, reflecting the influence of traditional family priorities and gender roles on educational decisions for women. Families may prioritize childbearing over education, perceiving women primarily as caregivers. This could raise the opportunity cost of educating women and reinforce gender stereotypes, leading to less emphasis on women's educational needs. Despite its intention to balance population dynamics, the policy might inadvertently continue gender inequality in education. These outcomes suggest potential social problems like increased gender inequality, ethnic disparities, and added family economic burdens, underscoring the importance of a balanced approach that addresses both demographic challenges and gender equity.

9 Conclusion

This comprehensive study's regression analysis provides insightful revelations on the significant impact of China's two-child policy on women's educational attainment. The findings are multifaceted, shedding light on how policy implementation intersects with women's educational opportunities. At the heart of the analysis is the 'DID' variable, symbolizing the policy, which demonstrates a pronounced negative correlation with women's education levels. The policy's implication of an additional child correlates significantly with reduced educational attainment among women, a result that extends beyond statistical data to reflect profound real-world consequences on women's empowerment and societal rights. Despite its modest numerical value, the coefficient of -0.062 from the Difference-in-Differences analysis represents a 6.2 percent reduction in women's educational expenditure due to the Two-Child Policy, compared to the control group, which carries significant societal and gender-related implications.

The study meticulously highlights the negligible influence of control variables like age, nationality, health status, urban residency, income, and purchasing ability on the policy's effect on women's education. This consistency across different model specifications underlines the policy's dominant and unaltered impact, emphasizing its primary role in shaping women's educational outcomes. Employing the Difference-in-Differences (DID) methodology, the study reinforces these findings, evidencing the consistent and more pronounced negative correlation with the integration of additional control variables. This observation validates the DID approach's efficacy in reducing omitted variable bias, indicating that previous analyses might have underestimated the policy's impact. The statistical significance of the policy effect, marked by a p-value less than 0.01, signifies a substantial decrease in women's educational engagement, necessitating urgent attention from policymakers, educators, and women's rights advocates for effective countermeasures.

Moreover, the implications of this study extend to broader policy considerations. The significant influence of the two-child policy on women's educational prospects suggests unintended ramifications on women's empowerment and socioeconomic status, calling for a critical reassessment of the policy's design to better support women's education and career opportunities. Future research should explore the long-term effects of the policy and its mechanisms on women's education. In summary, this study articulates the considerable, multifaceted impact of the two-child policy on women's education in China, highlighting the importance of deliberate policy analysis and societal engagement to advance discussions on gender equality and the rights of women.

References

[1] Joshua Angrist and William N Evans. Children and their parents' labor supply: Evidence from exogenous variation in family size, 1996.

[2] Kasey Buckles. Understanding the returns to delayed childbearing for working women. American Economic Review, 98(2):403–407, 2008.

[3] Kristin F Butcher and Anne Case. The effect of sibling sex composition on women's education and earnings. The Quarterly Journal of Economics, 109(3):531–563, 1994.

[4] Avraham Ebenstein. The "missing girls" of china and the unintended consequences of the one child policy. Journal of Human resources, 45(1):87–115, 2010.

[5] Xuan Jiang. Family planning and women's educational attainment: Evidence from the one-child policy. Contemporary Economic Policy, 38(3):530–545, 2020.

[6] Nancy Qian. Missing women and the price of tea in china: The effect of sex-specific earnings on sex imbalance. The Quarterly journal of economics, 123(3):1251–1285, 2008.

[7] Xiaoyu Wu. Fertility and maternal labor supply: Evidence from the new two-child policies in urban china. Journal of Comparative Economics, 50(2):584–598, 2022.

[8] Bing Xu and Maxwell Pak. Gender ratio under china's two-child policy. Journal of Economic Behavior & Organization, 119:289–307, 2015.

[9] Yuanting Zhang and Franklin W Goza. Who will care for the elderly in china?: A review of the problems caused by china's one-child policy and their potential solutions. Journal of aging studies, 20(2):151–164, 2006.

[10] Ying Zhou, Nan Jia, and Tianchi Yang. The quantity–quality trade-off related to investment in healthy human capital: new evidence from the implementation of the "selective two-child policy" in china. Journal of Asian Economics, 76:101347, 2021.

Appendix

Table 6: Evolution Process of the Two-Child Policy

Implementation Scope	Area Code	Implementation Date	Method of Implementation
Singleton Second Child			
Zhejiang Province	33	January 17, 2014	Revision of provincial fertility regulations
Jiangxi Province	36	January 18, 2014	
Anhui Province	34	January 23, 2014	
Tianjin City	12	February 14, 2014	
Beijing City	11	February 21, 2014	
Guangxi Zhuang Autonomous Region	45	March 1, 2014	
Shanghai City	31	March 1, 2014	
Shaanxi Province	61	March 1, 2014	
Sichuan Province	51	March 20, 2014	
Chongqing City	50	March 26, 2014	
Gansu Province	62	March 26, 2014	
Liaoning Province	21	March 27, 2014	
Hubei Province	42	March 27, 2014	
Guangdong Province	44	March 27, 2014	
Qinghai Province	63	March 27, 2014	
Jilin Province	22	March 28, 2014	
Jiangsu Province	32	March 28, 2014	
Hunan Province	43	March 28, 2014	
Yunnan Province	53	March 28, 2014	
Fujian Province	35	March 29, 2014	
Inner Mongolia Autonomous Region	15	March 31, 2014	
Heilongjiang Province	23	April 22, 2014	
Guizhou Province	52	May 17, 2014	
Ningxia Hui Autonomous Region	64	May 28, 2014	
Shanxi Province	14	May 29, 2014	
Hebei Province	13	May 30, 2014	
Shandong Province	37	May 30, 2014	
Hainan Province	46	June 1, 2014	
Henan Province	41	June 3, 2014	
Universal Second Child			
Nationwide	86	January 1, 2016	National legislation

The Effect of Community Choice Aggregation Programs on Household Electricity Costs: Evidence from California counties

Spriha Pandey

Abstract

This study investigates the impact of Community Choice Aggregation (CCA) programs on household electricity costs in California against a backdrop of rising energy expenses and the need for transitioning to renewable sources. CCAs have emerged as a solution for local governments to have greater control over their energy mix. Employing a stacked difference-in-differences event study model, the analysis reveals a significant decline in the rate of increase of annual household electricity costs following CCA implementation, with renters experiencing larger reductions compared to homeowners. The study finds that, among renters, households in counties that have implemented CCAs experience an annual electricity cost increase that is $261.60 less compared to households in non-CCA counties. These findings highlight the potential of CCAs to alleviate household energy burdens. Data constraints and the study's geographical focus on California, however, constrain generalizability. Nonetheless, the research provides important insights for policymakers navigating the adoption of CCAs to mitigate electricity costs.

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1 Introduction

Rising energy costs as well as greenhouse gas emissions have become a cause for great concern, and a central matter of policy debate, across the United States. California's electricity prices are among the highest in the country and these costs fall disproportionately on low-income customers, renters, and marginalized groups (California Divide 2023). According to a study by UC Berkeley's Haas Business School, California's Pacific Gas & Electric customers pay about 80% more per kilowatt-hour than the national average (Newsroom Berkeley Haas 2022). Furthermore, Southern California Edison charged 45% more than the national average, while San Diego Gas & Electric charged double. Even low-income residents who are enrolled in subsidy programs such as the California Alternate Rates for Energy pay more than the average American (Next 10 2021). This is because, as high-income households opt for alternate options like rooftop solar, low-income households pay a greater proportion of the fixed costs related to the electricity grid.

In the recent past, Community Choice Aggregation (CCA)—also called Municipal Aggregation – has gained prominence as an effective measure of giving communities (towns, municipalities, or counties) the option to choose the fraction of their electrical energy that comes from renewable energy (RE) sources (US EPA 2022). At present, most Americans receive their electricity from investor-owned utilities, also called IOUs (Wu and Howarth 2023). However, ten states—including California—have enacted legislation that authorizes local governments to purchase electricity on behalf of their residents and businesses from an alternative supplier while still receiving transmission and distribution services from their existing utility provider (US EPA 2022). By aggregating the purchasing power of their residents through CCAs, local governments promise to lower the cost of electricity through increased leverage against competitive utilities and give residents more control over the composition of their energy source mix (O'Shaughnessy et al. 2019).

The paper analyzes the distributional aspects of CCAs in California using a twofold approach. First, I compare the household electricity costs of counties that have adopted CCAs to household electricity costs of those that have not using a stacked difference-in-differences regression with fixed effects. I further study the correlation between per-capita installed solar capacity by county in 2018 and household electricity costs in 2021, dividing counties with and without CCAs into two groups. Some CCAs are known to generate electricity as well but this data is not available for California. However, since CCA generation is rare, I will assume that it would not drastically affect results. Furthermore, since the analysis spans multiple years (over a decade) and stops in 2022, if a CCA started generating electricity recently, it would not affect the analysis. In Section 2, I review current literature while in Sections 3 and 4, I discuss methodology and data. In Section 5, I present the results along with heterogeneity and robustness checks, and I conclude with a discussion of implications and limitations in Section 6.

The difference-in-differences analysis in this study finds no significant reduction across all households except in cases where the household heads have not completed high school and where the household income is lesser than the median household income of the county. However, the analysis finds that among renters, for households in treatment counties, the annual household cost of electricity has risen by \$261.60 less post-CCA implementation when compared to households in comparison counties. The findings for renters are robust across various specifications and the reductions are similar across various demographic groups, with the largest reductions in cases where the household heads have not completed high school. There are no significant reductions for homeowners. Greater savings for renters can be explained through a variety of reasons, the most salient of which may be a lack of control over electricity sources. Homeowners are more likely to install solar panels, opt out of CCAs, or opt in to get more renewable energy due to higher income, which can increase electricity prices for them (Horne, Kennedy, and Familia 2021). Furthermore, a larger fraction of renters are typically low-income and may have increasing access to California's policy initiatives aimed at reducing energy prices for low-income households (Hahn and Metcalfe 2021). Nonetheless, in this manner, this study provides a quantitative measure of the impact of CCAs on energy burdens and renewables—especially in marginalized households—to aid future policymaking.

2 Literature Review

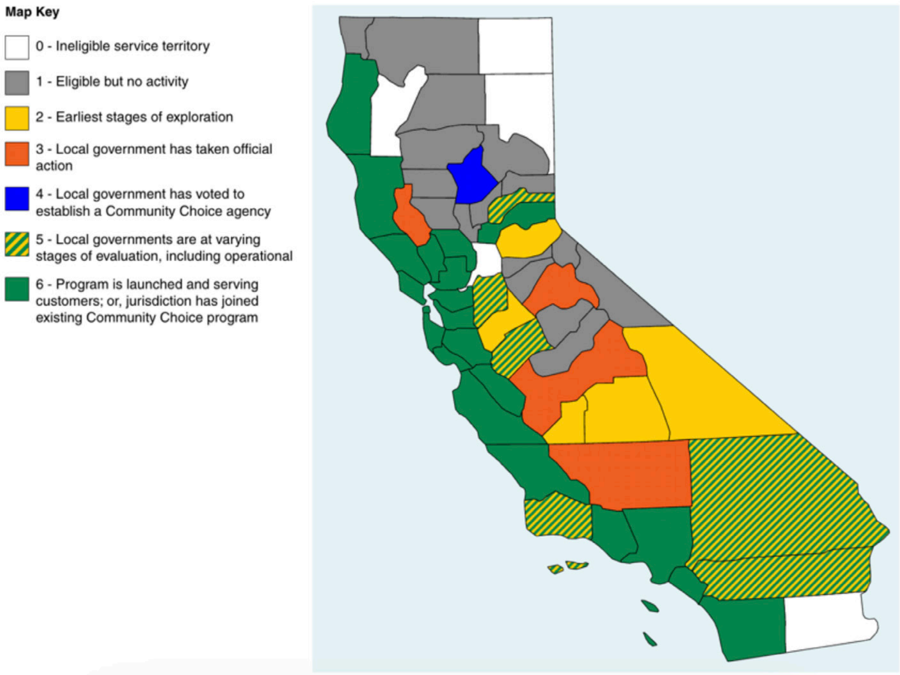
O'Shaughnessy et al. (2019) estimate that approximately 750 CCAs procured about 42 million megawatt-hours (MWh) of electricity on behalf of about five million customers in 2017 across the eight states that allow CCAs, with 8.9 million MWh of that being renewable. As more states are enrolled, O'Shaughnessy et al. (2019) argue that community-driven demand for voluntary green power (i.e., customer-chosen renewable energy) could change grid-wide electricity portfolios by increasing the number of RE (renewable energy) generators and take the RE procurement number to 28.9 million MWh. CCAs have become an especially effective tool in California for enabling local climate action. Across the state, 182 cities and counties have become members of one of the 23 CCAs, serving more than 30% of the state's population (and up from <1% in 2010) (Trumbull et al. 2020). A particularly interesting feature of CCAs is their "opt out" mechanism. When a municipality decides to join a CCA, all residents are automatically enrolled but can opt out (US EPA 2022). This leads to higher participation rates and sets the stage for econometric analysis due to status-quo bias.

While multiple facets of CCAs have been extensively studied in scholarly research—including effectiveness (Kennedy and Rosen 2021), challenges, impact on renewable energy markets (Trumbull et al., 2020), equity considerations (Scheier and Kittner 2022), and its relation to distributed generation capacity (Fikru and Canfield 2024)—no study looks at the household-level impact of CCAs, especially when it comes to comparing household energy burdens (defined as the ratio of household electricity bill to income) across demographic and socioeconomic measures. This study is pertinent for a variety of reasons. Scheier & Kittner (2022) find substantive evidence that while the RE transition has accelerated, equity has not kept pace. In the United States, 16% of households experience energy poverty—presently defined as spending more than 6% of household income on energy expenditures. More than 5.2 million households above the Federal Poverty Line face energy poverty, and these households are disproportionately Black, Hispanic, and Native American. Lukanov and Krieger (2019) find persistently lower levels of solar photovoltaic (PV) adoption in disadvantaged communities, suggesting clear distributive and equity impacts of existing RE incentives.

CCAs face a unique challenge when it comes to maximizing energy equity. RE is often expensive, and a community opting for high levels of solar, thermal or wind energy may face higher energy costs than regular utilities—and this cost is uniformly applied to all households. So far, CCAs have overcome this dichotomy through a tiered plan. There is a standard option that customers are enrolled in, as well as an opt-in "greener" option at a price premium (US EPA 2022) – something homeowners may be more likely to do due to higher overall income. These opt-ins are generally sourced from local renewables. While many sources argue that CCAs have succeeded in achieving low costs, greater distributional justice, and a higher percentage of renewable in the energy mix (Trumbull et al. 2020) (O'Shaughnessy et al. 2019), no study attempts to measure distributional justice at the household level. This aspect is especially important for policymakers looking to make the energy transition for equitable.

California offers a unique setting for analyzing household-level impacts. California enabled CCA legislation as early as 2001 but the first CCA was not set up till 2010. Since then, many municipalities have set them up over multiple years (Figure 1). Since most CCAs in California are set up at the county level, they allow me to study household energy burdens using census data. As seen in Figure 1, some counties are labeled 0 or "ineligible service territories." This is because these areas have municipal-owned utilities – wherein the utility is non-investor-owned and is already run by the municipal government.

Figure 1: California Map of CCA Program Status by County (The Climate Center, 2020)



This study takes advantage of the fact that several counties have CCA programs in counties that are already serving customers with neighboring ones that do not have such programs to set up an event study model. Deng and Rotman (2023) use a somewhat similar approach and setting to study the relationship between CCA and distributed electricity generation development. Fikru and Canfield (2024) also study the relationship between green energy purchases and CCAs in a similar fashion but focus solely on residential customer data and results from Silicon Valley Clean Energy—one of the CCAs in California.

3 Methodology

This paper's methodology takes advantage of the different levels and timing of CCA implementation across counties in California. From Figure 1, all counties with a rating of 6, i.e., where a program has been launched and is serving customers as of 2022, were categorized as having CCAs (i.e., treatment counties). All other counties (ratings 0-5) were categorized as not having CCAs (comparison counties). This difference within California allows me to study the impact of CCA-provided energy on household energy burdens compared to IOU-provided energy. An empirical challenge faced in this design is that CCAs have been implemented in different years in different counties (Table 1).

Table 1: California CCA Programs by Year of Implementation (CalCCA, 2020)

Year of launch	**Name of CCA Program**	**Counties**
2010	Marin Clean Energy	Contra Costa, Marin, Napa, Solano
2014	Sonoma Clean Power	Mendocino, Sonoma
2015	Lancaster Choice Energy	Los Angeles (only Lancaster)
2016	Clean Power SF, Peninsula Clean Energy	San Francisco, San Mateo
2017	Redwood Coast Authority, Silicon Valley Clean Energy, PRIME, Apple Valley Choice Energy	Humboldt
2018	Monterey Bay Community Power (now called: central Coast Community Energy), East Bay Community Energy, Solar Energy Alliance, Pioneer Community Energy, San Jose Clean Energy, Rancho Mirage Energy Authority, Clean Power Alliance, Valley Clean Energy, San Jacinto Power, King City Community Power	Alameda, Los Angeles (rest), Monterey, Placer, San Benito, San Bernardino, San Diego, San Joaquin, San Luis Obispo, Santa Clara, Santa Cruz, Ventura, Yolo
2020	Desert Community Energy, Western Community Energy, Orange County Power Authority	Orange, Riverside
2021	Santa Barbara Clean Energy	Santa Barbara

This makes it difficult to run a simple difference-in-differences regression with a post- and pre-period as this period is different across counties. This paper circumvents this challenge through the following equation:

$$Y_{hctg} = \alpha + \delta_{tg} + \gamma_{cg} + \sum_{k} \beta_k I[t - T_c = k] + \epsilon_{ctg} \quad (1)$$

When the treatment effect can differ by treatment groups and over time, there are numerous causal parameters of interest: the average treatment effect (ATT) is a function of treatment group *g*, where a group is defined by when units are first treated (e.g., counties treated in 2010 and counties treated in 2014 are in separate groups), and time period *t*. This method was used by Cengiz et al. to study the effect of minimum wage on low-wage jobs (2019).

Here y_{hctg} represents the outcome variable of interest or the household level energy burden for a household *h* in county *c* at time *t* in cohort *g*. γ_{cg} and δ_{tg} are county and year fixed effects respectively while ε_{ctg} is the error term and α is a constant. They are allowed to vary across cohorts of adopters. This is important for ensuring that the comparison group only consists of non-adopters, not adopters at other points in time. T_c is the time period when treatment begins for county *c*, and $I[t - T_c = k]$ is an indicator for being *k* years from the treatment starting. This indicator variable takes the value of 1 when the difference between time *t* and the event time T_c equals *k*, and it is 0 otherwise. As evidenced by Table 1, T_c = {2010, 2014, 2015, 2016, 2018, 2020, 2021}. β_k is the coefficient of interest and captures the effect of CCAs on household energy burdens. It can be considered a vector of event-study coefficients. In simpler terms, β_k measures the effect of the event occurring at time T_c on the outcome variable y_{hctg} at different time points *t*, with different *k* values representing different time lags or leads from the event time. The summation over *k* captures the cumulative effect of the event over time. For every year of CCA implementation, there will be a unique treatment but the same clean (never treated) comparison group.

$$Y_{hctg} = \alpha + \delta_{tg} + \gamma_{cg} + \beta_1 I[t - T_c \geq 0] + \epsilon_{ctg} \tag{2}$$

Equation 2 has almost the same model as equation 1 but instead of an event time study which generates a coefficient for all lead and lag periods, it is a simple difference-in-differences analysis where the coefficient of interest is β_1. Specifically, it evaluates how CCAs influenced treatment counties after implementation compared to before, relative to the changes observed in the comparison counties during the same time frame. The models will return unbiased estimates if the error term is uncorrelated with the independent variables. In other words, if the treatment counties are, on average, the same as the comparison counties in ways that affect the outcome variable after adding controls. Thus, this event study model with stacked regression estimators helps capture the effect of the presence of CCA on household energy burden even with a staggered timeline of adoption. I test the heterogeneity of the results by calculating these coefficients for different types of households, with variations across demographic and socio-economic lines.

This paper also conducts a supplementary analysis using county-level solar capacity data from 2018. The equation is given as below:

$$Y_{hcg} = \beta_0 + \beta_1 ccac + \beta_2 solar + \beta_3 solarc * ccac + \epsilon_c \tag{3}$$

In this case, the outcome variable of interest is Y_{hc}, which is the household energy burden for a household h in county c. ε_c is the error term. Here, the variable solarc is a running variable that represents the solar capacity per capita in MWh in county *c*. The variable ccac is set to 1 if the county has a CCA program serving customers as of 2018 otherwise 0. β_1 represents the dollar change in household electricity costs due to the presence of CCA in 2018. β_2 represents the dollar change in household electricity costs for every additional unit of installed solar capacity per capita. β_3 is the coefficient of interest and represents the percentage point change in household energy burden due to a one MWh increase in the per capita solar capacity of a county for counties that have CCAs compared to counties that do not. This equation is then put subject to the same heterogeneity conditions as before, by calculating these coefficients for different types of households with variations across demographic and socio-economic lines.

4 Data

The household-level data in California on electricity costs was sourced from IPUMS American Community Survey (ACS) (Ruggles et al. 2023). The American Community Survey is conducted by the U.S. Census Bureau and collects detailed demographic, social, economic, and housing information from a sample of households across the United States. ACS also provided demographic variables about the household head, such as race, age, sex, education level, and technical data about the house itself, such as the age of the structure, size of the house, ownership status, number of rooms, etc. The data of interest spans from 2006–2022 and contains household income and electricity data for the years 2006, 2011, 2016, 2021, and 2022. The data on the presence and start date of CCAs was sourced from the Climate Center and CalCCA, non-profit organizations that have made their research datasets publicly available. Data on county-level solar capacity was obtained from PSE Health Energy, which in turn sourced it from the most recent edition of Lawrence Berkeley National Lab's (LBNL) Tracking the Sun 2018 database (Bolinger and Seel 2018). The next section details the variables of the dataset used for each of the two analyses in this paper.

The key dataset used in the analysis in this paper is a repeated cross-sectional dataset with household-level characteristics of counties recorded over several years. The units of analysis are households in treatment and comparison counties compared over time. As mentioned above, the household-level data is from 2006, 2011, 2016, 2021, and 2022. However, CCAs were enacted in different years (2010, 2014, 2016, 2017, 2018, and 2020). Thus, I create an event study model (Equation 1) to see the impact of CCA implementation on household energy burdens depending on how many years it has been since CCA was enacted. Hence, for a treatment county where CCA was enacted in 2014, pre-treatment household electricity data is available for 2006 (eight years before treatment) and 2011 three years before treatment), as well as two, seven and eight years after treatment.

Table 2: Summary Statistics for Key Variables

	Treatment group		Comparison group	
	(1)	(2)	(3)	(4)
Variable	Owner	Renter	Owner	Renter
Cost of electricity	1542.62	1023.92	1658.16	1326.21
	(1406.84)	(1055.39)	(1383.89)	(1218.59)
House area in acres	0.94	0.35	1.01	0.53
	(0.27)	(0.48)	(0.20)	(0.53)
Cost of gas	2328.12	3504.90	2433.05	3519.50
	(3262.49)	(3873.17)	(3257.86)	(3807.94)
Cost of water	1402.31	5080.55	1463.84	5116.47
	(2273.27)	(3822.12)	(2372.07)	(3791.96)
Cost of fuel	7812.38	8062.20	7532.50	7935.93
	(1949.90)	(1457.50)	(2431.07)	(1724.72)
Number of rooms	6.23	3.99	6.17	4.46
	(2.00)	(1.77)	(1.80)	(1.69)
House built before 1980	0.61	0.63	0.46	0.54
	(0.49)	(0.48)	(0.50)	(0.50)
Number of families	1.07	1.15	1.05	1.11
	(0.33)	(0.52)	(0.28)	(0.45)
Household income	111176	60029.04	79969.89	41140.73
	(122555.80)	(71863.81)	(81451.82)	(47571.39)
Value of House	636078.30		326886.30	
	(746785.60)		(415949.00)	
Rent		1244.40		771.94
		(854.39)		(514.87)

Table 2: Summary Statistics for Key Variables (Continued)

Household head characteristics				
Men	0.55	0.50	0.53	0.46
	(0.50)	(0.50)	(0.50)	(0.50)
Age	55.95	45.04	54.78	44.12
	(15.43)	(16.40)	(15.94)	(16.65)
White	0.62	0.50	0.69	0.57
	(0.48)	(0.50)	(0.46)	(0.49)
Completed high school	0.92	0.85	0.89	0.80
	(0.27)	(0.36)	(0.31)	(0.40)
Observations	330841	211741	417382	230223

All monetary values are in real dollars with base year 2023. Standard deviations in parentheses.

The key variables for the analysis annual electricity costs, event time (the variable k in the methods section, calculated by subtracting CCA start year from current year), and the binary variable has_{cca}, depending on whether the county the household is in has an operational CCA. This variable is an indicator for the treatment group. The analysis will have year and county-fixed effects (countyfip). Electricity is the dependent variable while has_{cca} interacted with time is the independent variable. The controls included in this analysis include house ownership status (rent or owner), household income (in dollars), house area in acres, rent in dollars (for renters), cost of gas, water and fuel, the value of the house in dollars (for homeowners), number of rooms, the year the house was built, the number of families living in the house, as well as the sex, age, race, and education status of the household head.

It is important to note here that I only consider household heads to not oversample larger families. The summary statistics of these variables are summarized in Table 2, and are divided by owners (columns 1 and 3) and renters (columns 2 and 4) in treatment and comparison counties. On average, owners have larger houses and higher incomes. However, renters pay higher electricity costs in comparison counties as compared to renters in treatment counties. Water costs are considerably higher for renters across all counties. This may be due to a variety of reasons such as sub-metering or lack of subsidies for hard-to-reach renters due to socioeconomic barriers. In many rental properties, especially multifamily buildings, water costs are often sub-metered, meaning each unit is individually metered for water usage. This can result in higher costs for renters because they are billed directly for their water consumption, whereas homeowners might have their water costs included in their property taxes or homeowners association fees (Davis 2021).

To conduct a stacked regression analysis, I stack this dataset by creating "waves," i.e., dividing counties into cohorts (variable g in the methods section) depending on CCA start year. For example, for the wave 2010 the treatment counties are those which got CCA in 2010 and comparison counties are those which are yet to get CCAs. All others are dropped. I similarly create datasets for 2014, 2015, 2017, 2018, and 2020. These are stacked or appended on top of each other. The comparison group is the same for all waves.

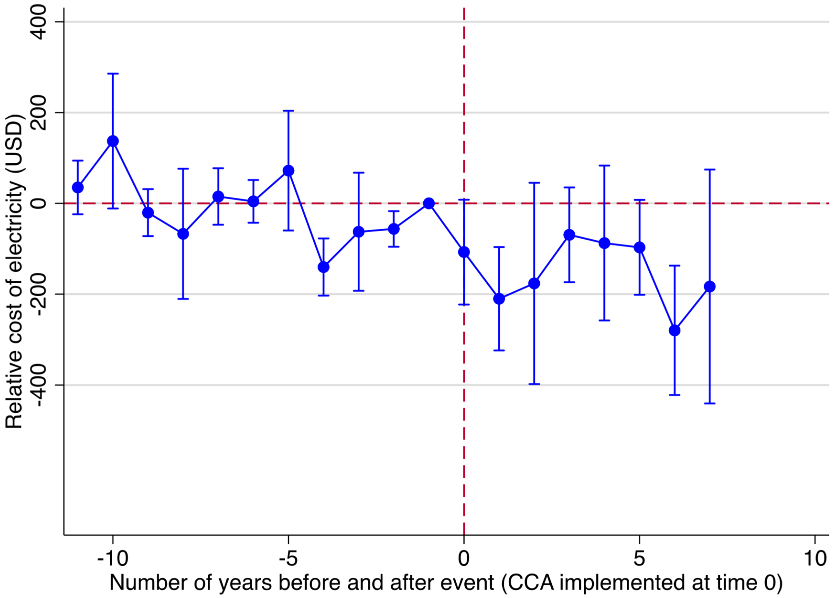
5 Results

This study compares trends in the household electricity costs of counties that have adopted CCAs to those that have not, using a fixed effects model. The paper analyzes the distributional aspects of CCAs, and hypothesizes, as stated by proponents of CCAs, that households in counties with CCAs will on average pay less for electricity as compared to households in counties without CCAs. The regression analysis is represented in equations 1 and 2 in the methods section, where β_k measures the effect of the event occurring at time T_c on the outcome variable yhctg at different time points t, with different k values representing different time lags or leads from the event time. This event study model with stacked regression estimators helps capture the effect of the presence of CCA on household electricity costs even with a staggered timeline of adoption.

The key results for the full sample—renters and owners pooled—can be seen in Figure 2. The error bars represent 90% confidence intervals, with the event time (k) on the x-axis. As seen, there is a statistically significant drop ($68.22) in the annual household of electricity at k = 1 (and also at k = 6), or the year after CCA is adopted, for counties that implement CCAs when compared to counties that do not, with the reference year being the year prior to the implementation of CCA (k = -1). This is a 5.94% decline given the mean annual electricity cost of $1147.42 in California households. It is important to here to note that overall, electricity costs are increasing in California. Therefore, this "decline" should be interpreted as how much "lesser" the cost increase is in treatment counties. However, there is also a significant difference in the costs of electricity in CCA vs. non-CCA counties prior to CCA implementation at k=-2 and -4 which seems to suggest that costs may have been on a general downward trend in treatment counties as compared to comparison counties. [1]

1 All monetary values are in real dollars with base year 2023.

Figure 2: Event Study Analysis – Difference in Cost of Electricity for Households in CCA vs non-CCA Counties

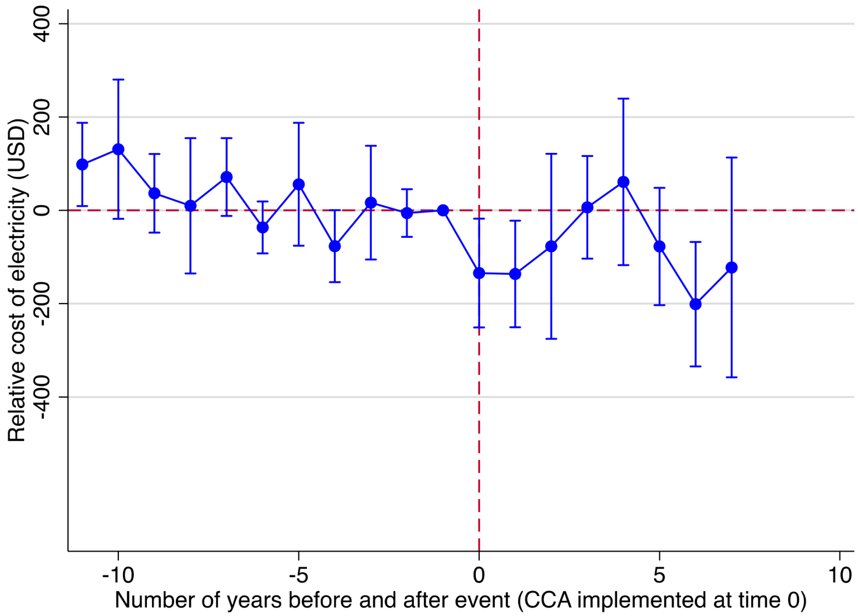


Notes: Sample incudes households from all California counties identifiable in ACS 5-year 5% percent samples of 2006, 2011, 2016, 2021, and 2022. Graph shows stacked difference-in-differences estimate (for the annual cost of electricity) on time of the event (CCA implementation). Regression model includes county-fixed effects and year fixed effects interacted with cohort-fixed effects (where a cohort consists of all counties that implemented CCA in a given year). The regression also includes controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. Only household heads are included in the analysis. All counties with event time less than -11 and greater than 7 were given event time values of -11 and 7 respectively. All monetary values are in real dollars with base year 2023. The error bars indicate 90 percent confidence intervals and standard errors are clustered at county level.

Figure 3 presents an event study similar to Figure 2 but restricts households based on ownership status. Figure 3a looks at house owners while controlling for the value of the house while 3b looks at renters and controls for rent. In the case of homeowners, there are no statistically significant pre-trends, but a slight drop in the year CCA is implemented. Overall, there is not much of an apparent effect for homeowners. In the case of renters, there are no distinct pre-trends towards rising or falling costs except in 2 or 3 years before CCA implementation where costs seem to rise by less than the year before CCA implementation. Furthermore, the costs rise by lesser post-CCA implementation in treatment counties. The pre-treatment significant differences may be due to the nature of the dataset where all event times are not aptly represented. It is important to note that there is a slightly downward trend three years before CCA implementation for renters. However, this trend is not significant for the overall population. Moreover, the downward trend becomes more pronounced and larger in magnitude post-CCA implementation. Given the nature of the dataset, only two counties (Mendocino and Sonoma) have data available at three years pre-CCA implementation for every county. Hence, it may be an attribute of these specific counties.

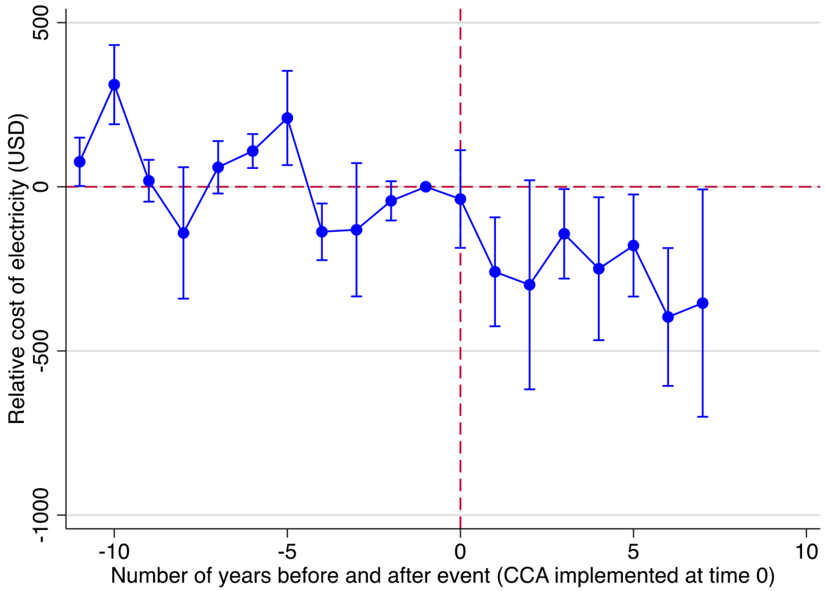
To overcome this noise, I put event times into 3-year buckets in Figure 4. As seen in Figure 4c, there is no longer a significant pre-trend where costs seem to rise by less than the year before CCA implementation. However, there is a slight downward trend which may be biasing post-period trends downward such that the magnitudes seem larger than their true value. Future research could benefit from annual datasets that can analyze subsets of counties with greater granularity.

Figure 3a: Event Study Analysis—Difference in Cost of Electricity for Households in CCA vs non-CCA Counties for House Owners



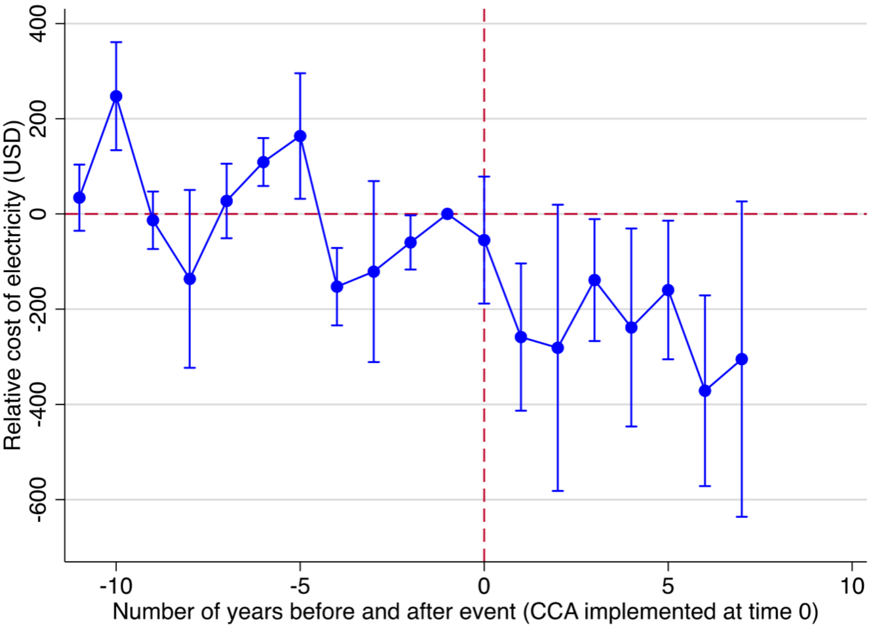
Notes: Sample incudes households from all California counties identifiable in ACS 5-year 5% percent samples of 2006, 2011, 2016, 2021, and 2022. Graph shows stacked difference-in-differences estimate (for the annual cost of electricity) on time of the event (CCA implementation). Regression model includes county-fixed effects and year fixed effects interacted with cohort-fixed effects (where a cohort consists of all counties that implemented CCA in a given year). The regression also includes controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. Fig 3a. includes a control for the value of the house, and Fig 3c. includes a control for rent. Only household heads are included in the analysis. All counties with event time less than -11 and greater than 7 were given event time values of -11 and 7 respectively. All monetary values are in real dollars with base year 2023. The error bars indicate 90 percent confidence intervals and standard errors are clustered at the county level.

Figure 3b: Event Study Analysis—Difference in Cost of Electricity for Households in CCA vs non-CCA Counties for House Renters



Notes: Sample incudes households from all California counties identifiable in ACS 5-year 5% percent samples of 2006, 2011, 2016, 2021, and 2022. Graph shows stacked difference-in-differences estimate (for the annual cost of electricity) on time of the event (CCA implementation). Regression model includes county-fixed effects and year fixed effects interacted with cohort-fixed effects (where a cohort consists of all counties that implemented CCA in a given year). The regression also includes controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. Fig 3a. includes a control for the value of the house, and Fig 3c. includes a control for rent. Only household heads are included in the analysis. All counties with event time less than -11 and greater than 7 were given event time values of -11 and 7 respectively. All monetary values are in real dollars with base year 2023. The error bars indicate 90 percent confidence intervals and standard errors are clustered at the county level.

Figure 3c: Event Study Analysis—Difference in Cost of Electricity for Households in CCA vs non-CCA Counties for House Renters Without Controls for Rent



Notes: Sample incudes households from all California counties identifiable in ACS 5-year 5% percent samples of 2006, 2011, 2016, 2021, and 2022. Graph shows stacked difference-in-differences estimate (for the annual cost of electricity) on time of the event (CCA implementation). Regression model includes county-fixed effects and year fixed effects interacted with cohort-fixed effects (where a cohort consists of all counties that implemented CCA in a given year). The regression also includes controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. Fig 3a. includes a control for the value of the house, and Fig 3c. includes a control for rent. Only household heads are included in the analysis. All counties with event time less than -11 and greater than 7 were given event time values of -11 and 7 respectively. All monetary values are in real dollars with base year 2023. The error bars indicate 90 percent confidence intervals and standard errors are clustered at the county level.

The results of the difference-in-difference analysis from Equation 2 are summarized in Table 3.

Table 3: The impact of CCAs on the Household Cost of Electricity

	(1)	(2)	(3)	(4)	(5)
Variables	All households	All households	Owners	Renters	Renters
Electricity cost:					
Post CCA	-91.39	-126.8	-89.06	-227.5**	-267.9**
	(85.08)	(88.23)	(84.14)	(106.8)	(110.5)
Mean (year before event)	1147.82	1147.82	1229.15	972.51	972.51
Value of the house (in 1000s of dollars)			0.189***		
			(2.26e-05)		
Rent					0.132***
					(0.0135)
Controls		X	X	X	X
County x Cohort FE	X	X	X	X	X
Year x Cohort FE	X	X	X	X	X
Observations	112,969,349	112,969,349	66,207,695	46,761,654	46,761,654
R-squared	0.162	0.273	0.240	0.310	0.313

Columns (2), (3) and (4) include controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. (3) has a control for value of the house, and (5) has control for rent. All monetary values are in real dollars with base year 2023. Robust standard errors clustered at county level are in parentheses. Statistical significance levels: *** p<0.01, **p<0.05, * p<0.10.

As seen in Table 3, there is no significant impact of the presence of CCAs on the annual cost of electricity for all households. This may be due to the fact that not all counties are captured during all event times due to the mismatch between the years of ACS data and the years of implementation. The significant results in Figure 4, therefore, stress the importance of an event study model for this analysis as the mismatch of data makes it impossible to observe every county in the year right after CCA is implemented. As mentioned in the methods, cost of electricity data is not available for all years which implies that the year that CCA goes into effect is not captured for all counties or households. However, despite these data constraints, the value is still significant for individuals who are renting their house. Among renters (columns 4 and 5), for households in counties that have CCAs, the annual household cost of electricity rises by $267.90, or approximately 28%, lesser when CCA is implemented when compared to households in counties that get CCAs. These results are significant at a 5% level. Furthermore, controlling for the rent increases the change in household electricity costs as well as the R-squared, implying that rent is an explanatory variable and has to be controlled for.

Figure 4a: Event Study Analysis – Difference in Cost of Electricity for Households in CCA vs non-CCA Counties for All Households (3-year buckets)

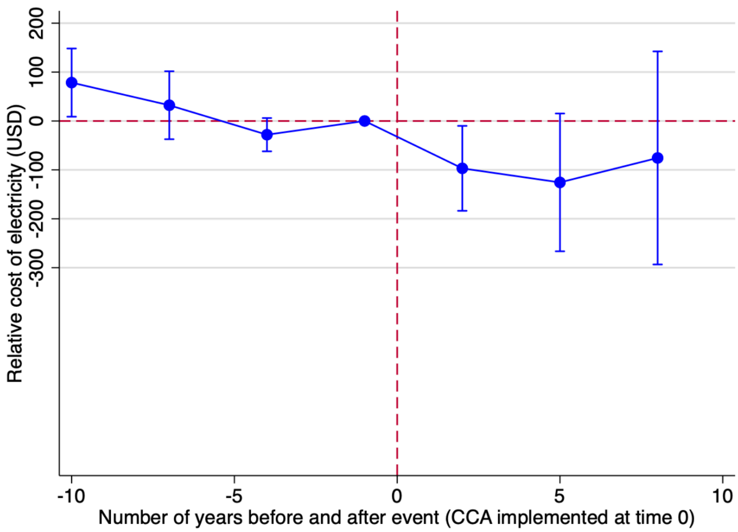


Figure 4b: Event Study Analysis – Difference in Cost of Electricity for Households in CCA vs non-CCA Counties for House Owners (3-year buckets)

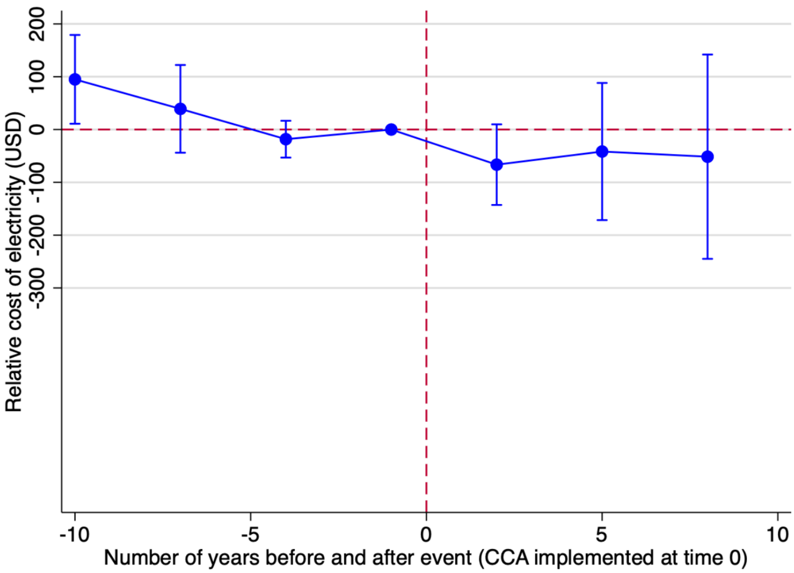
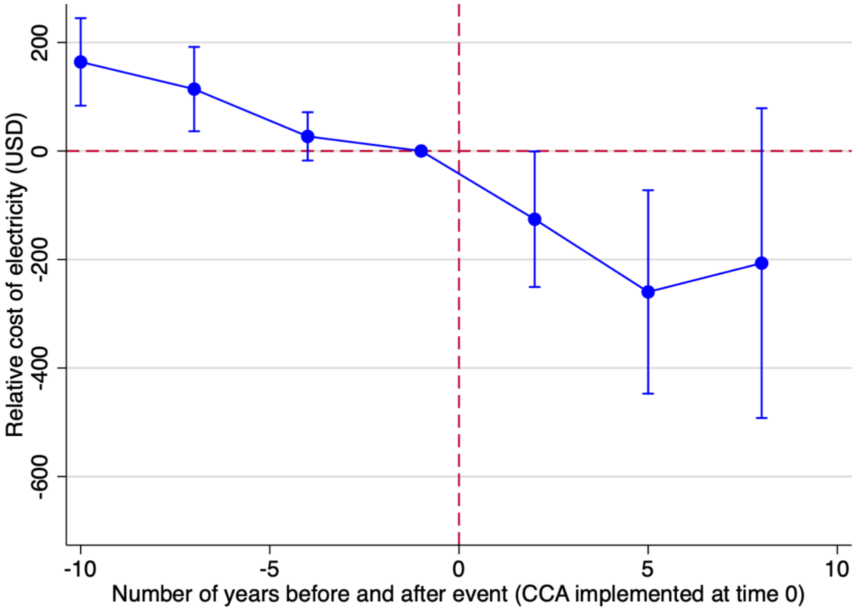


Figure 4c: Event Study Analysis – Difference in Cost of Electricity for Households in CCA vs non-CCA Counties for House Renters (3-year buckets)



Notes: Sample incudes households from all California counties identifiable in ACS 5-year 5% percent samples of 2006, 2011, 2016, 2021, and 2022. Graph shows stacked difference-in-differences estimate (for the annual cost of electricity) on time of the event (CCA implementation). Regression model includes county-fixed effects and year fixed effects interacted with cohort-fixed effects (where a cohort consists of all counties that implemented CCA in a given year). The regression also includes controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. Fig 4b. includes a control for the value of the house, and Fig 4c. includes a control for rent. Only household heads are included in the analysis. All counties with event time less than -10 and greater than 8 were given event time values of -10 and 8 respectively. All monetary values are in real dollars with base year 2023. The error bars indicate 90 percent confidence intervals and standard errors are clustered at the county level.

In Figure 3, while there is a decline in prices after *k=0*, or when CCA is implemented, for both groups, this decline is more consistent and steadier among renters, in agreement with Table 3. This may be attributed to a variety of reasons. Distinctions based on whether electricity costs are included in rent may be driving some of the variation. Landlords that include utilities in rent may not be passing on the full cost of utilities to their renter to stay competitive with rent prices. The analysis looks at total energy cost and not per unit energy prices, which means that renters may be seeing greater declines because they use more energy overall. Research suggests that renting households are found to use approximately 9% more electricity than non-renters when controlling for location, socioeconomic, and many appliance-quantity controls (BestPaul et al. 2021). It is difficult to ascertain if this is the case from my dataset as it only has total electricity costs and does not separate electricity prices and usage in units. However, overall, homeowners pay higher electricity costs.

The key results for the model in Equation 2 are in Table 4. In this model, installed solar energy capacity is added as a variable of interest as renewable energy is more expensive. The solar installed capacity data is from 2018, while all other data is from ACS 2021. This a data constraint as reliable per capita solar capacity data was unavailable for 2021. It is further important to note that installed solar capacity might not always translate to used solar energy in a county—for example, in cases where solar fields in one county provide energy to houses in a nearby county. However, this is unlikely. As seen in the table, households in counties with more solar capacity have higher costs, and in counties with CCAs have lower costs. Among those with CCA, counties with more solar have lower costs. However, these are strictly correlational due to the lack of data availability.

While data is constrained only to 2021, results suggest that among households in counties that have CCAs, more solar capacity is associated with lower electricity costs. These findings are in agreement with the qualitative analysis by Greenleaf et al. (Greenleaf et al. 2023) who find that CCA can advance energy justice by expanding access to affordable, renewable energy for renters and other types of residents.

Table 4: The Impact of CCAs and Installed Solar on Household Annual Cost of Electricity

	(1)	(2)	(3)
Variables	All households	Owners	Renters
Cost of electricity			
Installed solar capacity	5.653***	5.420***	6.891***
(in kW per capita)	(0.564)	(0.776)	(0.764)
Has CCA	-153.7***	-229.8***	-225.3***
	(16.79)	(22.99)	(23.47)
Solar*CCA	-4.160***	-3.374***	-5.626***
	(0.574)	(0.789)	(0.777)

Table 4: The Impact of CCAs and Installed Solar on Household Annual Cost of Electricity (Continued)

Value of house		0.000224***	
		(6.44e-06)	
Rent			0.0952***
			(0.00672)
Controls	X	X	X
Observations	125,973	79,909	46,064
R-squared	0.152	0.123	0.187

All columns include controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, and indicators for whether the household head is male, white, and has at least received a high school education. All monetary values are in real dollars with base year 2023. Robust standard errors clustered at county level are in parentheses. Statistical significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

In section 5.1, I study the impact of CCA on the household cost of electricity for different demographics, and in section 5.2, I subject the significant results for renters from Table 3 to various robustness checks.

5.1 Heterogeneity

Table 5: The Impact of CCAs on the Household Cost of Electricity

	Non-white household head			Female household head		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Cost of electricity	All households	Owners	Renters	All households	Owners	Renters
Post CCA	-129.0	-84.77	-234.8**	-120.2	-81.03	-255.1**
	(91.60)	(90.18)	(107.0)	(96.29)	(92.34)	(117.3)
Mean (year before event)	1212.38	1227.84	1196.35	1076.33	1220.20	759.79
Value of the house		X			X	
Rent			X			X
Controls	X	X	X	X	X	X
County x Cohort FE	X	X	X	X	X	X
Year x Cohort FE	X	X	X	X	X	X
Observations	44,081,529	22,439,072	21,642,457	54,699,177	30,337,778	24,361,399
R-squared	0.260	0.224	0.290	0.276	0.246	0.310

All columns include controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. All monetary values are in real dollars with base year 2023. Robust standard errors clustered at county level are in parentheses. Statistical significance levels: *** p<0.01, **p<0.05, * p<0.10.

Next, I test the heterogeneity of the results by calculating these coefficients for different types of households, with variations across demographic and socio-economic lines. Specifically, this section looks at how the demographic characteristics of household heads change the results (Tables 5 and 6), and the age of the house changes the results (Table 7). For all groups, the results show coefficients for all households in the first column, and for specifically owners and renters in the next two columns. The controls are the same as Table 3, and include house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. For owners, I control for house value and for renters, I control for rent.

Table 6: The Impact of CCAs on the Household Cost of Electricity

	Household head has not completed high school			Household income is below median household income in county		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Cost of electricity	All households	Owners	Renters	All households	Owners	Renters
Post CCA	-183.3***	-102.0	-298.7***	-123.5*	-85.61	-216.8**
	(65.01)	(68.09)	(89.34)	(70.59)	(70.09)	(84.72)
Mean (year before event)	1227.84	1598.89	881.52	1080.13	1189.38	962.37
Value of the house		X			X	
Rent			X			X
Controls	X	X	X	X	X	X
County x Cohort FE	X	X	X	X	X	X
Year x Cohort FE	X	X	X	X	X	X
Observations	14,555,514	6,369,122	8,186,392	56,881,230	25,777,782	31,103,448
R-squared	0.282	0.257	0.310	0.246	0.220	0.282

All columns include controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. All monetary values are in real dollars with base year 2023. Robust standard errors clustered at county level are in parentheses. Statistical significance levels: *** p<0.01, **p<0.05, * p<0.10.

In Table 5, column 3, we see that among households with household heads of color, annual household electricity costs are reduced by $234.80 for renters after CCAs are implemented in treatment counties as compared to comparison counties. This number is $216.80 for low-income households (defined as household income lower than the respective county's median household income) (Table 6, column 6), and $255.10 for households that have a female household head (Table 5, column 6). It is noteworthy that the results in column 4 of Table 6—i.e., for low-income households—are significant at the 10% level. This suggests that low-income households are benefitting more from CCAs. Furthermore, there is a statistically significant reduction in costs for households with household heads who did not complete high school for all households as well as the renter sub-group. Overall, we see that the electricity savings are similar among different groups but smaller ($234) for households with incomes below the median. However, this may also be explained by the fact that these households already pay lower prices for electricity due to lower consumption and government subsidies or that they use lower amounts of energy overall and thus benefit greatly from per-unit price reductions due to CCAs.

Table 7: The Impact of CCAs on the Household Cost of Electricity

	House built before 1980			House built after 1980		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Cost of electricity	All households	Owners	Renters	All households	Owners	Renters
Post CCA	-159.2	-124.8	-293.0**	-104.6	-71.00	-239.4**
	(103.1)	(104.1)	(110.6)	(75.79)	(69.64)	(111.3)
Mean (year before event)	1139.60	1220.17	994.32	1161.63	1242.09	920.25
Value of the house		X			X	
Rent			X			X
Controls	X	X	X	X	X	X
County x Cohort FE	X	X	X	X	X	X
Year x Cohort FE	X	X	X	X	X	X
Observations	61,699,823	34,597,232	27,102,591	51,269,526	31,610,463	19,659,063
R-squared	0.287	0.258	0.318	0.255	0.221	0.307

All columns include controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. All monetary values are in real dollars with base year 2023. Robust standard errors clustered at county level are in parentheses. Statistical significance levels: *** p<0.01, **p<0.05, * p<0.10.

In Table 7, column 1, we see that among houses built before 1980, annual household electricity costs are reduced by $293 after CCAs are implemented in treatment counties as compared to comparison counties. This number is $239.40 for houses built after 1980. I divided the timeline in 1980 because in 1978, California adopted building codes designed to reduce the energy used for heating and cooling (Novan et al. 2022). Since the 1970s California's residential electricity consumption per capita has stopped increasing (Levinson 2014). Older houses see a greater reduction in energy costs, which may, once again be a result of these houses being less energy-efficient and using more energy overall. Greater energy use would result in greater savings when per-unit electricity costs go down.

5.2 Robustness Checks

Another concern with the nature of CCA implementation in California is that some counties are not eligible for CCAs at all due to the presence of a municipal utility (as opposed to a private one) and might therefore not be suitable as a comparison group. In Figure 1, these ineligible counties are represented by 0. These ineligible service territories are dropped in column (1) of Table 6, which looks only at renters. Similarly, there can be concerns that not all cities in a county get CCAs at the same time or at all (Los Angeles in Table 1). In Column (2) and Column (3) of Table 6, the sample is restricted to households in counties where over 50% of the population is enrolled in CCAs and 100% of the population is enrolled in CCAs respectively. There is a statistically significant decline in electricity costs in all 3 cases, suggesting that the results are robust. Furthermore, the magnitude of reductions increases with the rate of participation, further confirming that CCA participation is driving price reductions.

Table 8: The Impact of CCAs on the Household Cost of Electricity for Renters

	(1)	(2)	(3)	(4)	(5)
Variables	Eligible counties	Counties with >50% participation	Counties with 100% participation	All households	All households
<u>*Cost of electricity*</u>					
Post CCA	-273.8**	-305.5***	-420.6***	-218.8***	-213.6***
	(113.6)	(107.0)	(110.7)	(77.17)	(77.57)
Mean (year before event)	1147.82	1147.82	1147.82	1147.82	1147.82
Population density				X	
Democratic share					X
Rent	X	X	X	X	X
Controls	X	X	X	X	X
County x Cohort FE	X	X	X	X	X
Year x Cohort FE	X	X	X	X	X
Observations	46,119,271	33,390,127	25,913,569	37,063,977	37,063,977
R-squared	0.312	0.323	0.315	0.304	0.304

All columns include controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. All monetary values are in real dollars with base year 2023. Robust standard errors clustered at county level are in parentheses. Statistical significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

Electricity prices are dependent on demand, and it may be possible that more densely populated areas face greater prices of electricity. In column 4 of Table 8, population density is controlled for but does not impact results by a significant amount. Similarly, there are concerns regarding inherent differences between counties that have CCAs versus not because county governments vote on CCA implementation. The democratic share of counties is therefore controlled for in Column 7 using election data from the closest election cycle to every analysis year. This does not significantly impact results either.

As seen in Table 6, costs rose less for low-income households. It may be possible that subsidy programs for low-income households in treatment counties are driving the prices to rise at lower rates. Hence, in Table 9, I only focus on renters in households with income above the median household income for the county. The impact is still significant as well as larger in magnitude, meaning that subsidies for low-income families are not the driver of the observed impact. In Column (2) of Table 9, I only focus on counties where all jurisdictions within the county have CCA (i.e., 100% participation).

Table 9: The Impact of CCAs on the Household Cost of Electricity for Renters in Households with Income Above the Median Household Income for the County

	(1)	(2)
Variables	All households	Counties with 100% participation
<u>*Cost of electricity*</u>		
Post CCAs	-305.5**	-452.2***
	(124.6)	(128.3)
Rent	X	X
Controls	X	X
County x Cohort FE	X	X
Year x Cohort FE	X	X
Observations	15,658,206	8,350,299
R-squared	0.172	0.166

All columns include controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. All monetary values are in real dollars with base year 2023. Robust standard errors clustered at county level are in parentheses. Statistical significance levels: *** p<0.01, **p<0.05, * p<0.10.

It may also be hypothesized that changes in income may be driving changes in electricity consumption, and therefore prices. In Table A1 in the appendix, household income is used as the outcome variable. Household income seems to rise over time and increases with the presence of CCAs. Hence, decreasing income could be driving the lower costs.

6 Conclusion

The study finds that CCAs result in lower electricity cost increases among renters. This finding is significant because it points to the benefits of CCA. Amid escalating concerns over climate change, understanding the efficacy of CCA programs is critical. As municipalities seek ways to reduce their carbon footprint and promote renewable energy adoption, CCAs offer a localized approach that empowers communities to have greater control over their energy sources. Furthermore, the findings of this research provide valuable insights for policymakers. Differential results for renters and homeowners point to a need for potentially differentiating the policy solutions. By demonstrating the quantitative impact on household electricity costs, the study offers empirical evidence to support the adoption of such programs in other regions of California as well as the US. Overall, it contributes to the growing body of literature on energy economics and policy by shedding light on the effectiveness of CCAs as a mechanism for achieving energy affordability.

While this study supports the literature and its initial hypothesis based on the claims of CCA proponents, it faces some limitations. Potential migration effects are not accounted for, wherein households might relocate to or from counties with CCAs, thus altering energy demand and prices. Renters have significant results while owners do not which may suggest that homeowners are absorbing some of the costs to control rents from going up. Data that separates whether utilities are included in rent or not could help address this problem in future analyses. Furthermore, the reliance on ACS 5-year samples from 2000 to 2022 may overlook annual fluctuations or short-term trends in household electricity prices, warranting caution in interpreting the long-term effects of CCA adoption. Additionally, the study primarily focuses on the total cost of electricity rather than the actual consumption patterns, which could provide valuable insights into efficiency gains or behavioral shifts induced by CCAs. It may be possible that people consume less when prices go up or vice-versa. Finally, the generalizability of the findings is constrained by the study's focus on California counties, limiting their applicability to regions with different regulatory environments, energy market structures, and socio-economic dynamics. Addressing these limitations in future research could offer a more comprehensive understanding of the impact of CCAs on household energy prices.

References

[1] BestPaul, Rohan, Paul J. Burke, and Shuhei Nishitateno. 2021. "Factors Affecting Renters' Electricity Use: More Than Split Incentives." The Energy Journal 42 (5): 1–18. https://doi.org/10.5547/01956574.42.5.rbes.

[2] Bolinger, Mark, and Joachim Seel. 2018. "Utility-Scale Solar: Empirical Trends in Project Technology, Cost, Performance, and PPA Pricing in the United States – 2018 Edition." 1477381. https://doi.org/10.2172/1477381.

[3] "California Divide." n.d. CalMatters. Accessed March 3, 2024. http://calmatters.org/category/california-divide/.

[4] "Celebrating 10 Years of CCA in California! – CalCCA." n.d. Accessed February 3, 2024. https://cal-cca.org/celebrating-10-years-of-cca-in-california/.

[5] Cengiz, Doruk, Arindrajit Dube, Attila Lindner, and Ben Zipperer. 2019. "The Effect of Minimum Wages on Low-Wage Jobs*." The Quarterly Journal of Economics 134 (3): 1405–54. https://doi.org/10.1093/qje/qjz014.

[6] "Community Choice Energy - The Climate Center." n.d. Accessed February 3, 2024. https://theclimatecenter.org/our-work/clean-energy/community-choice-energy/.

[7] Davis, Martha F. 2021. "Hidden Burdens: Household Water Bills, 'Hard-to Reach' Renters, and Systemic Racism." Seton Hall Law Review 52 (5): 1461–1512.

[8] Deng, Jun, and Robin Rotman. 2023. "Does the Community Choice Aggregation Approach Advance Distributed Generation Development? A Case Study of Municipalities in California." Journal of Cleaner Production 413 (August): 137451. https://doi.org/10.1016/j.jclepro.2023.137451.

[9] "Designing Electricity Rates for An Equitable Energy Transition | Next 10." n.d. Accessed March 3, 2024. https://www.next10.org/publications/electricity-rates.

[10] Fikru, Mahelet G., and Casey Canfield. 2024. "Choosing Both/and: Encouraging Green Energy Purchases in Community Choice Aggregation." Energy Policy 185 (February): 113949. https://doi.org/10.1016/j.enpol.2023.113949.

[11] Greenleaf, Maron, Sarah H. Kelly, Reed Cole, Julia Griffin, Donald Kreis, April Salas, and Sydney Wuu. 2023. "'Tool for a Just Transition? Community Choice Aggregation and Energy Justice in New Hampshire and Beyond.'" Energy Research & Social Science 105 (November): 103287. https://doi.org/10.1016/j.erss.2023.103287.

[12] Hahn, Robert W., and Robert D. Metcalfe. 2021. "Efficiency and Equity Impacts of Energy Subsidies." American Economic Review 111 (5): 1658–88. https://doi.org/10.1257/aer.20180441.

[13] Horne, Christine, Emily Huddart Kennedy, and Thomas Familia. 2021. "Rooftop Solar in the United States: Exploring Trust, Utility Perceptions, and Adoption among California Homeowners." Energy Research & Social Science 82 (December): 102308. https://doi.org/10.1016/j.erss.2021.102308.

[14] Kennedy, Sean F, and Bailey Rosen. 2021. "The Rise of Community Choice Aggregation and Its Implications for California's Energy Transition: A Preliminary Assessment." Energy & Environment 32 (2): 262–80. https://doi.org/10.1177/0958305X20927381.

[15] Levinson, Arik. 2014. "California Energy Efficiency: Lessons for the Rest of the World, or Not?" Journal of Economic Behavior & Organization 107 (November): 269–89. https://doi.org/10.1016/j.jebo.2014.04.014.

[16] Lukanov, Boris R., and Elena M. Krieger. 2019. "Distributed Solar and Environmental Justice: Exploring the Demographic and Socio-Economic Trends of Residential PV Adoption in California." Energy Policy 134 (November): 110935. https://doi.org/10.1016/j.enpol.2019.110935.

[17] Novan, Kevin, Aaron Smith, and Tianxia Zhou. 2022. "Residential Building Codes Do Save Energy: Evidence from Hourly Smart-Meter Data." The Review of Economics and Statistics 104 (3): 483–500. https://doi.org/10.1162/rest_a_00967.

[18] O'Shaughnessy, Eric, Jenny Heeter, Julien Gattaciecca, Jenny Sauer, Kelly Trumbull, and Emily Chen. 2019. "Empowered Communities: The Rise of Community Choice Aggregation in the United States." Energy Policy 132 (September): 1110–19. https://doi.org/10.1016/j.enpol.2019.07.001.

[19] O'Shaughnessy, Eric J., Jenny S. Heeter, Julien Gattaciecca, Jennifer Sauer, Kelly Trumbull, and Emily I. Chen. 2019. "Community Choice Aggregation: Challenges, Opportu-

nities, and Impacts on Renewable Energy Markets." NREL/TP--6A20-72195, 1494285. https://doi.org/10.2172/1494285.

[20] "Report Reveals Inequity in Electricity Pricing, Calls for Rate Reform to Help Fight Climate Change." 2022. Haas News | Berkeley Haas. September 22, 2022. https://newsroom.haas.berkeley.edu/research/report-reveals-inequity-in-electricity-pricing-calls-for-rate-reform-to-help-fight-climate-change/.

[21] Ruggles, Steven, Sarah Flood, Matthew Sobek, Daniel Backman, Annie Chen, Grace Cooper, Stephanie Richards, Renae Rodgers, and Megan Schouweiler. 2023. "IPUMS USA: Version 14.0." [object Object]. https://doi.org/10.18128/D010.V14.0.

[22] Scheier, Eric, and Noah Kittner. 2022. "A Measurement Strategy to Address Disparities across Household Energy Burdens." Nature Communications 13 (1): 288. https://doi.org/10.1038/s41467-021-27673-y.

[23] Trumbull, Kelly, Julien Gattaciecca, and J R DeShazo. n.d. "The Role of Community Choice Aggregators in Advancing Clean Energy Transitions:"

[24] US EPA, OAR. 2022. "Learn about Green Power Market." Overviews and Factsheets. January 24, 2022. https://www.epa.gov/green-power-markets/learn-about-green-power-market.

[25] Wu, Victor Y., and Richard Howarth. 2023. "Shifting Partisan Public Opinion towards Community Choice Aggregation through Outreach and Awareness." PLOS ONE 18 (10): e0292136. https://doi.org/10.1371/journal.pone.0292136.

Appendix

Table A1 shows the difference-in-differences estimate for household income on time of event CCA implementation. Household income is increases for households in treatment counties post-implementations, even when the topcode (highest recorded income) is forcibly set to the same value. This value ($1,397,000) is the lowest recorded value of income among the highest incomes across years.

Table A1: The Impact of CCAs on the Household Income for Renters

	(1)	(2)
Variables	All households	All households but consistent topcode of $1,397,000
Household income		
Post CCA	4,247**	4,248**
	(1,857)	(1,856)
Controls	X	X
Rent	X	X
County x Cohort FE	X	X
Year x Cohort FE	X	X
Observations	46,761,654	46,761,654
R-squared	0.310	0.310

All columns include controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, whether the house was built before or after 1980, number of families living in the house, rent, and indicators for whether the household head is male, white, and has at least received a high school education. All monetary values are in real dollars with base year 2023. Robust standard errors clustered at county level are in parentheses. Statistical significance levels: *** p<0.01, **p<0.05, * p<0.10.

House electricity costs based on CCA participation within counties: The percentage participation variable was created by dividing the population of towns with fully functional CCAs by the total population of a county.

Figure A1: Event Study Analysis – Difference in Cost of Electricity for Households in CCA vs non-CCA Counties in 3-year Buckets for Counties with 100% Participation (All Households)

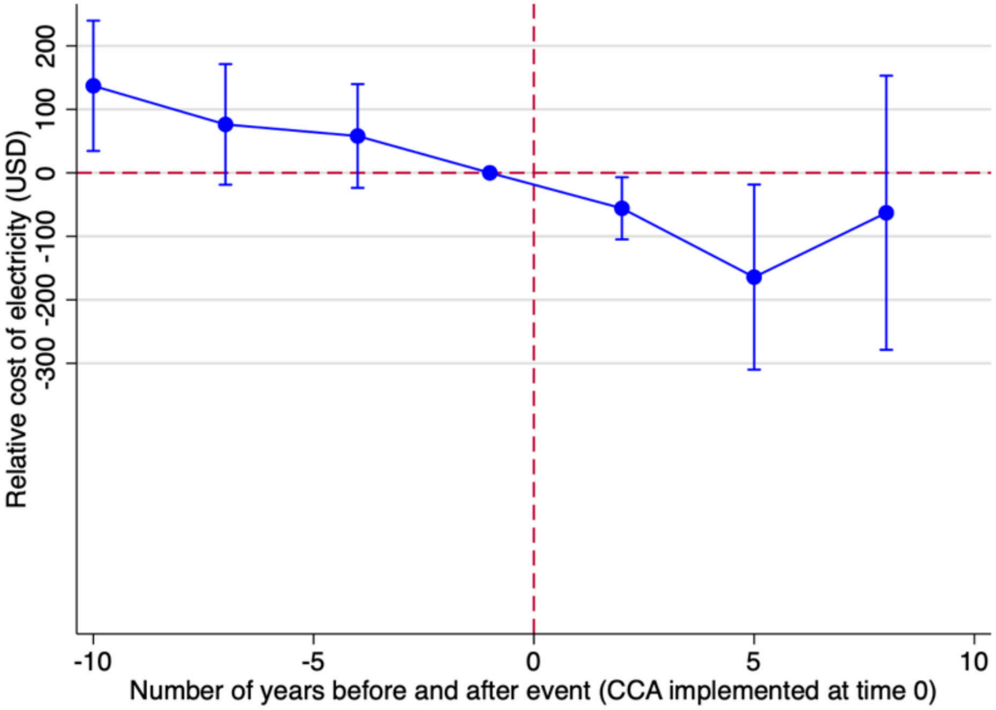
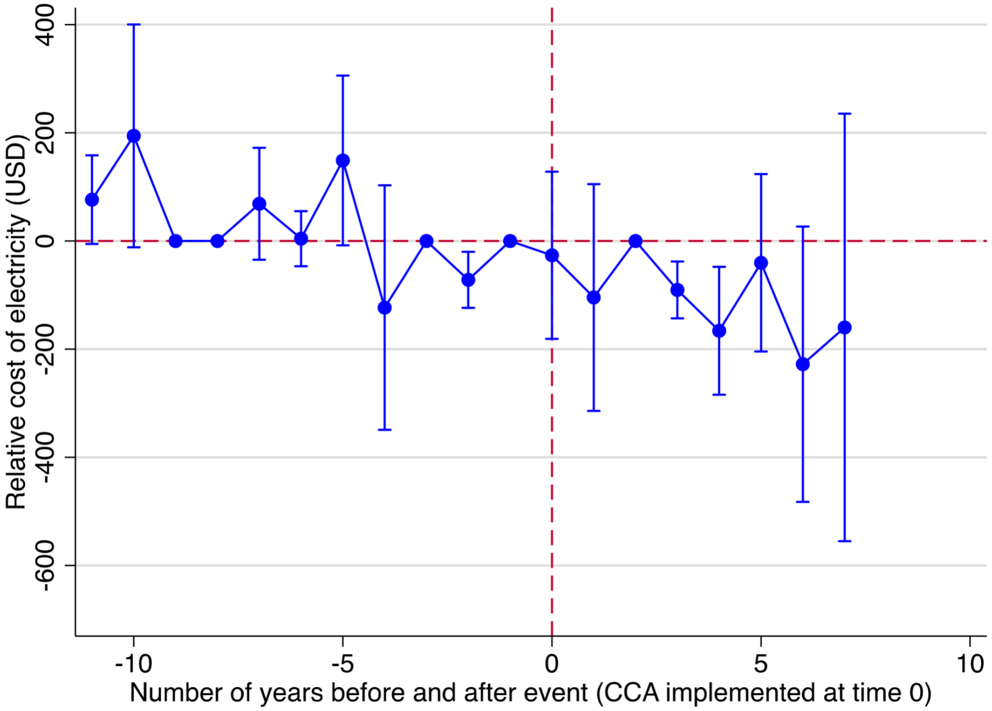


Figure A1: Event Study Analysis – Difference in Cost of Electricity for Households in CCA vs non-CCA Counties in 3-year Buckets for Counties with 100% Participation (Renters Only)



Notes: Sample incudes households from all California counties identifiable in ACS 5-year 5% percent samples of 2006, 2011, 2016, 2021, and 2022. Graph shows stacked difference-in-differences estimate (for the annual cost of electricity) on time of the event (CCA implementation). Regression model includes county-fixed effects and year fixed effects interacted with cohort-fixed effects (where a cohort consists of all counties that implemented CCA in a given year). The regression also includes controls for house ownership status, house size in acres, annual cost of gas, water and fuel, number of rooms, rent, whether the house was built before or after 1980, number of families living in the house, total annual household income, and indicators for whether the household head is male, white, and has at least received a high school education. Only household heads are included in the analysis. All counties with event time less than -8 and greater than 7 were given event time values of -8 and 7 respectively. All monetary values are in real dollars with base year 2023. The error bars indicate 90 percent confidence intervals and standard errors are clustered at the county level.

Emerging Market Economies: Monetary Spillovers in a DSGE Framework[1]

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December 2024

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List of Abbreviations

AE: Advanced economy
CEC: Commodity exporting country
CIC: Commodity importing country
DSGE: Dynamic stochastic general equilibrium
EME: Emerging market economy
FED: Federal Reserve
GDP: Gross domestic product
ITR: Inertial Taylor Rule
MMB: Macroeconomic Model Database
QE: Quantitative Easing
STR: Standard Taylor Rule
UMP: Unconventional monetary policy
US: United States

List of Symbols

α	Share of the commodity in the production function
E_t	Expectations in period t
φ_{com}	Weight on commodity price fluctuations
φ_{core}	Weight on core inflation
$\varphi_{\mathcal{Y}}$	Weight on the efficient output gap
$\kappa_{\mathcal{Y}}$	Scaling factor determining the impact of the efficient output gap on core inflation
η_t	Elasticity of substitution of net global demand in period t
γ	Share of the commodity in the consumption basket
g_t	Preference shock in period t
M	Weighted average of the covariances and variances of and

$\mathfrak{M}_t$	Commodity production of the dominant exporter in period t
mc_t	Deviations in marginal costs in period t
π_t	Headline inflation in period t
$\pi_{Y,t}$	Core inflation in period t
Ψ_t	Commodity market markup in period t
ψ_t	Commodity markup deviation from the steady state in period t
Q_t	Real commodity price in period t
Δq_t	Commodity price change in period t
ρ	Correlation of commodity demand and supply shocks
r_t^e	Efficient policy rate in period t
σ_ψ	Standard deviation of commodity markup
σ_z	Standard deviation of commodity supply
u_t	Endogenous cost-push shock in period t
X_t	Supply of the fringe in period t
x	Standard deviation of the commodity demand shock relative to the supply shock
υ	Inverse Frisch labour supply elasticity
$\hat{\mathcal{Y}}_t^n$	Natural output gap in period t

$\hat{\mathscr{Y}}_t^e$	Efficient output gap in period t
$\mathscr{Y}_t^e$	Efficient output in period t
Z_t^{-1}	Marginal costs of the commodity exporters in period t
z_t	Productivity shock in period t

1 Introduction

Over the past few decades, the integration of financial markets and openness of trade have significantly increased (Georgiadis 2016). As a result of financial globalisation, the world economy is progressively experiencing large cross-country spillovers from monetary policies of systemic economies (Georgiadis and Jančoková 2020). Furthermore, empirical data suggests that spillover effects from monetary policy decisions of the United States (US) are substantial for emerging market economies (EMEs) (Degasperi, Hong, and Ricco 2021; Kalemli-Özcan 2019). To mitigate monetary policy spillovers, it is crucial to accurately discern the underlying dynamics and sources of shocks. Filardo et al. (2018) address this issue in a dynamic stochastic general equilibrium (DSGE) framework by assessing the optimal policy response to different drivers of commodity price swings. Connecting empirical data with DSGE frameworks, this paper addresses how monetary policy spillover effects function and propagate onto EMEs and discusses ways to limit these spillovers. Building on previous literature and testing Filardo's model (Filardo et al. 2018) in the Macroeconomic Model Database (MMB) (Wieland et al. 2012; Wieland et al. 2016), I hypothesise that correctly identifying the sources of a shock and a less volatile policy reaction can lead to fewer economic fluctuations and might limit monetary policy spillovers.

The paper is structured into the following sections. Section 2 is a literature review that analyses how, under which conditions, and to what extent monetary policy spillovers affect EMEs. After highligting key spillover channels and country characteristics that amplify spillovers, I showcase the consequences of spillovers for EMEs drawn from model simulations and empirical data in the literature. Following the literature review of spillovers in Section 2, the subsequent sections focus on implications drawn from a DSGE model on how monetary policy can limit spillovers. Section 3 explains a multi-country DSGE model by Filardo et al. (2018), which addresses commodity price fluctuations and associated spillover effects. I present the main quantitative characteristics of this model and their qualitative implications for monetary policy, laying the foundation for Section 4. In Section 4, I test their model in the MMB (Wieland et al. 2012; Wieland et al. 2016) to showcase the effects of fiscal policy and productivity shocks on the economy and the consequences arising from different policy rules trying to counteract these shocks. Finally, Section 5 discusses the policy recommendations arising from findings in the previous literature and present work.

2 Literature Review: A Critical Analysis of Monetary Policy Spillovers

2.1 Monetary Policy Spillover Channels and their Relative Importance

Monetary policy decisions of a country are transmitted through various channels to foreign advanced economies (AEs) and EMEs. A substantial body of literature demonstrates that US monetary policy has significant spillover effects on other countries (Tillmann 2016; Ahmed, Akinci, and Queraltó 2021; Apostolou and Beirne 2019; Hofmann and Takáts 2015; Anaya, Hachula, and Offermanns 2017; Chen et al. 2016). Therefore, in this section, the paper will mainly refer to the US as the country from which monetary policy spillovers onto EMEs originate.

The classic Mundell-Fleming model identifies two international transmission channels of monetary policy: the trade channel and the exchange rate channel (Mundell 1963; Fleming 1962). According to Degasperi, Hong, and Ricco (2021), a US interest rate increase causes a domestic contraction. Consequently, US demand for US and foreign goods decreases, displaying the trade channel. Additionally, an increase in US interest rates causes an appreciation of the dollar and, ceteris paribus, depreciation of the EME's currency, assuming a flexible exchange rate. Subsequently, EME goods become relatively cheaper, thereby increasing US demand for foreign goods, referred to as the exchange rate channel. Furthermore, Degasperi, Hong, and Ricco (2021) also assess the propagation of spillovers through the commodity and oil price channel and the financial channel: Considering that commodities are integral to the global economy, the oil and commodity price channel serves a crucial role in price spillovers. A tightening of US monetary policy leads to decreasing demand for oil and other commodities. Subsequently, the headline inflation in the US and foreign countries contracts, whereas core inflation remains unchanged at first but can be affected in a second-round effect[3]. According to Degasperi, Hong, and Ricco (2021), the financial chan-

3 Inflation refers to the consumer price index in the paper of Degasperi, Hong, and Ricco (2021).

nel is a pivotal channel in the transmission of real variables. If the Federal Reserve (FED) increases the interest rate, investments in the US would become more attractive which leads to portfolio rebalancing, resulting in foreign capital outflow, inducing upward pressure on foreign long-term yields and downward price revisions of foreign assets. Another reason in the case of the US would be a dampening of global economic expectations leading to a risk-off scenario with EMEs witnessing further capital outflows. Degasperi, Hong, and Ricco (2021) also find that cross-border bank lending and international credit channels magnify the effect of the financial channel by further limiting the risk-taking of organizations lending to EMEs. The financial channel is substantial for EMEs since they are affected more strongly than developed economies due to the dominant role of dollar-denominated credit to EMEs (Bräuning and Ivashina 2020).

Degasperi, Hong, and Ricco (2021) argue that the exchange rate and trade channels have limited impact as they tend to offset each other. Furthermore, the financial channel dominates in the transmission to real variables and the oil and commodity channel primarily determines price spillovers. However, this assessment is not universally applicable. Firstly, the channels affect each other ((Bruno and Shin 2015), making an accurate attribution of each channel arduous. Secondly, the importance of each channel can depend on country-specific characteristics. For instance, the trade channel might depend on trade openness and the dependence on foreign trade as well as on other characteristics which will be analysed in the next section. Finally, assessing the importance of spillover channels by analysing spillovers from the US can be subject to general criticism. Spillovers encompass not only direct effects from one country to another but also operate through second-round spillover effects via other countries (Agénor and Da Silva 2022).

2.2 How Characteristics of Emerging Market Economies Shape Spillovers

As the previous section demonstrates, monetary policy spillover effects propagate to foreign countries through various channels. However, the extent of monetary policy spillovers differs depending on the specific characteristics of EMEs. Given that global trade enables spillover effects, the extent of trade openness and trade relations measurably affects the impact of monetary policy spillovers. More open economies experience a more pronounced and persistent decline in output, with inflation decreasing for a longer period (Degasperi, Hong, and Ricco 2021). Furthermore, specific ties of trade and a higher dependence on a foreign economy make a country more susceptible to spillovers. For instance, the European Central Bank policy heavily impacts central Eastern European economies due to their strong trade relations, whereas the specific influence of the FED on this region is limited (Walerych and Wesołowski 2021). Next to trade ties, dollar trade invoicing also magnifies adverse monetary policy spillover effects because the currency depreciation of the EME after US monetary tightening cannot translate into lower prices of home goods abroad, leading to a decline in EME exports (Arezki and Liu 2018).

Another vital characteristic is the exchange rate regime. Exchange rate regimes can be categorized into floaters, managed floaters, and crawling pegs (Degasperi, Hong, and Ricco 2021). A US monetary policy increase leads to an EME contraction in output, inflation, stock prices, and risk appetite for all these regimes. However, the effect is the least for floaters and the most severe for peggers. Countries with floating exchange rates witness capital outflows, whereas peggers are mostly unaffected. Managed floaters raise interest rates to prevent capital outflows and substantial depreciation, even though they suffer from greater real and nominal spillovers compared to floaters (Degasperi, Hong, and Ricco 2021). Therefore, trying to limit exchange rate volatility can prove counterproductive for EMEs due to risk premia forcing EMEs to substantially increase interest rates to offset exchange rate changes following the higher US policy rate. This in turn might increase credit costs and spreads resulting in lower gross domestic product (GDP) growth (Kalemli-Özcan 2019).

However, the impact of spillovers under certain exchange rate regimes also depends on other characteristics. For instance, a strong balance sheet, characterized by a low level of dollar debt, mitigates spillover effects since EMEs with a strong balance sheet are less vulnerable to currency depreciation. Conversely, an abundance of dollar-denominated debt poses a significant risk to EMEs since a dollar appreciation resulting from a FED rate hike increases the amount of debt for the EME as well as debt servicing costs (Ahmed, Akinci, and Queraltó 2021) and credit spreads (Arezki and Liu 2018). Furthermore, the currency premium increases when the domestic balance sheet of an EME deteriorates after a monetary tightening, leading to additional exchange rate depreciation and capital outflow. The underlying assumption is that foreign borrowing is affected more severely than domestic borrowing by enforcement frictions. It is harder for foreign creditors to supervise borrowers in an EME and enforce contracts with them than it is for domestic creditors, resulting in credit spreads. This in turn leads to a currency depreciation which can then cause losses in the EME's domestic balance sheet, magnifying the depreciation of the currency (Akinci and Queraltó 2018).

Finally, Kearns, Schrimpf, and Xia (2023) suggest that the extent of financial ties, including the amount of dollar-denominated debt, is the strongest determinant of spillovers. Other characteristics influencing spillovers include central bank credibility and the associated anchoring of inflation expectations with less credible central banks and unanchored inflation expectations causing larger spillovers (Ahmed, Akinci, and Queraltó 2021).

2.3 General Consequences of Conventional Monetary Policy Spillovers: An Analysis of Empirical Data and a DSGE Framework

A central challenge to studying general spillover consequences arises from the numerous heterogeneous characteristics of EMEs presented in the previous section. EMEs might be affected to different degrees depending on their characteristics, leading to differences in the optimal policy choice. To model these differences and the associated consequences, Ahmed, Akinci, and Queraltó (2021) implement a DSGE model which divides EMEs into vulnerable and non-vulnerable countries. Vulnerable EMEs are characterized as having fragile balance sheets with dollar-denominated debt, poorly anchored inflation expectations, and dollar export pricing. Non-vulnerable EMEs, in turn, have strong balance sheets, well-anchored inflation expectations, and domestic currency export pricing. Furthermore, their study differentiates between different origins of a shock in the US. Monetary tightening would either stem from a more hawkish policy stance, meaning an unexpected change in the policy rule, or a demand shock. Their model predicts that US monetary tightening resulting from a more hawkish policy stance causes an economic slowdown for all EMEs, albeit particularly negative for vulnerable EMEs. A stronger slowdown aligns with the disadvantageous characteristics of vulnerable EMEs like a decrease in exports due to dollar trade invoicing. In contrast, higher US interest rates stemming from higher US demand would lead to mildly positive spillovers to economic activity in EMEs with strong fundamentals since increased exports from higher overall demand outweigh tighter financial conditions. Consequently, central banks are in a better position to increase interest rates due to the initial economic boost from higher demand. Conversely, central banks of vulnerable EMEs face a dilemma. The initial boost in demand causes inflation to rise which in turn intensifies due to unanchored inflation expectations. At the same time, the US monetary tightening increases the dollar-denominated debt of vulnerable EMEs. Hence, monetary policy is forced to increase policy rates more strongly, leading to adverse consequences with economic slowdowns (Ahmed, Akinci, and Queraltó 2021).

Next to general consequences within a DSGE model, analysing the extensive empirical data of Degasperi, Hong, and Ricco (2021) allows for insight into the whole propagation of monetary policy spillover effects through different channels in a real-world context for the median EME: After a monetary tightening of the US, the global economy contracts with a delay. Furthermore, EMEs face currency depreciation. However, the exchange rate channel cannot compensate for the demand and financial channels. The exchange rate effect is also offset by dollar trade invoicing for the median EME which prevents foreign demand for EME goods from increasing. Overall demand decreases and a risk-off scenario arises which leads to portfolio rebalancing and subsequently decreasing asset demand in EMEs, capital flights and a higher risk premium due to the depressed economic situation and outlook. Consequently, financial and credit market conditions deteriorate, leading to a contraction of the stock market. These effects result in a contraction of EME output comparable to the decline in the US itself. Additionally, headline inflation drops more strongly than in the US within the representative data. This stands in contrast to rising prices following a demand-driven shock within the model of Ahmed, Akinci, and Queraltó (2021). A potential interpretation of the decrease is that in the empirical data, the trade, commodity, and financial channels outweigh the exchange rate channel for the median EME. Additionally, it is important to consider that in the sample data, many EMEs are commodity exporters and hence commodity price declines heavily contributed to the contraction of prices in the economy in general which might have been underestimated by the model. Following the different price reactions, the policy rate in the median case decreases (Degasperi, Hong, and Ricco 2021), whereas the policy rate in the model of Ahmed, Akinci, and Queraltó (2021) increases.

It is important to interpret the empirical findings with caution. Degasperi, Hong, and Ricco (2021) potentially overlook the multilateral intricacies of global linkages. In analysing linear relationships, monetary policy implications and spillover effects could be oversimplified. Iacoviello and Navarro (2019) close this gap and find with an extensive panel regression similar results. Nonetheless, the informative value of these analyses is ambiguous. The impact of US monetary policy on the individual country is heterogeneous and depends on the country-specific characteristics (Walerych and Wesołowski 2021). At the same time, related spillback effects should be considered. EMEs like systemically important middle-income countries with a large impact on commodity prices can also cause large spillovers (Agénor and Da Silva 2022). Therefore, in the future, empirical studies need to focus on a narrower classification of EMEs, for instance by introducing an analysis of the consequences of monetary policy on systemically important middle-income countries and related spillback effects while differentiating between different shocks.

2.4 Unconventional Monetary Policy Spillovers on EMEs

Given the extended periods of near-zero interest rates in many AEs from 2008 to 2018, novel unconventional measures were introduced to stimulate economic growth in the short run. Unconventional monetary policy (UMP) comprises multiple measures including negative interest rate policies, lending operations or credit policies, and quantitative easing (QE), accompanied by forward guidance (Fratto et al. 2021). In particular, QE plays a crucial role in causing spillovers (Chen et al. 2016). However, negative interest rate policies as well as lending operations or credit policies also cause spillovers (Fukuda 2018; Miyajima, Mohanty, and Yetman 2014). Furthermore, Moessner (2015) finds that, at the zero lower bound, forward guidance, meaning announcements on the future path of the federal funds rate, induces measurable equity price hikes across all countries and particularly in EMEs. However, it is conceivable that forward guidance can result in different reactions depending on the perception of investors to the announcements (Böck, Feldkircher, and Siklos 2021). Forward guidance might be perceived negatively if the guidance is an indicator that the slow economic growth persists longer than expected. In contrast, forward guidance indicating a tightening might even induce capital inflows via a risk-on effect if it signals investors that the economy performs better than expected. Furthermore, country-specific characteristics likely have an impact on the effectiveness of forward guidance and the associated spillovers. Forward guidance stemming from a less credible central bank might be perceived as not trustworthy, as suggested by Cole, Martínez-García, and Sims (2023). In general, these communication tools are used together with other unconventional monetary policy measures like QE, which gained importance in the aftermath of the 2008 global financial crisis. QE directly boosts the liquidity available by buying long-term bonds, thereby reducing interest rate spreads between long- and short-term treasuries. Likewise, they also target reducing corporate spreads, the difference between the Federal funds rate and the corporate borrowing rate, to bolster investment (Chen et al. 2016). Anaya, Hachula, and Offermanns (2017) assess that the overall consequences of QE are persistent increases in real and financial variables in EMEs. Following US QE measures and the rise in capital inflows in EMEs, equity returns and real output increase. Furthermore, the EME currency appreciates due to the capital inflow into EMEs. However, the impact of QE only persists in the short term with EME capital inflow fading away after around 6 months and real GDP growth staying above the trend for nearly one year (Anaya, Hachula, and Offermanns 2017). In general, EMEs are affected relatively strongly by UMP, with sovereign yields in some countries changing even more than in the US due to spillovers (Bowman, Londoño, and Sapriza 2015). However, the consequences of QE on EMEs are heterogeneous (Chen et al. 2016), as the case study of the next session will reveal. Furthermore, when assessing general spillover consequences, Fratzscher, Lo Duca, and Straub (2018) argue that QE effects on foreign economies depend on the economic environment, leading to time-varying effects. Therefore, chronologically analysing the varying spillover effects found by Fratzscher, Lo Duca, and Straub (2018) conveys a better understanding of the propagation of QE. The global financial crisis led to multiple rounds of QE, labelled QE1, QE2 and QE3. The FED introduced QE1 in late 2008 before the end of the global financial crisis. These measures lowered sovereign yields and increased equity prices, predominantly in the US. QE1 was accompanied by capital flows from EMEs into the US, probably because investors gained hope for a recovery of the US which induced a portfolio rebalancing. In contrast, QE2 in 2010 resulted in procyclical effects in EMEs through capital inflows, which was likely caused by lower macroeconomic uncertainty and a risk-on effect (Fratzscher, Lo Duca, and Straub 2018). Bowman, Londoño, and Sapriza (2015) find that in the case of QE3, the currencies of EMEs depreciated and stock prices declined in the first half of 2013. A possible explanation could be a capital outflow after an overheating of EMEs or expectations of an incoming full recovery of the US market, increasing its attractiveness for investment.

These results show that QE spillovers differ depending on the economic environment and demonstrate the dangers of cycles of expansions followed by recessions for EMEs due to reversals of capital flows back into developed economies, aligning with Tillmann (2016). Chen et al. (2016) point out that the spillovers of US monetary policy in EMEs can be a main source of financial instability. Furthermore, the shifts between conventional and unconventional measures lead to monetary policy uncertainty which persistently increases systematic financial risks across associated countries (Ouyang, Wei, and Baca 2022). At the same time, UMP could help at boosting economic growth and stabilise prices (Tran and Pham 2020). Therefore, the case study in the following section will provide a clearer view of the potential costs and benefits of UMP depending on the economic environment.

2.5 Case study: The Influence of Unconventional Monetary Policy on Brazil

After the financial crisis, Morgan Stanley (2013) identified five fragile countries – including Brazil – because of their vulnerability through large current account deficits, high inflation rates, high exchange rate volatility and low foreign reserves per total external debt. Brazil's reliance on foreign capital flows and its connection to the American economy make it susceptible to significant spillover effects, giving valuable insight into associated benefits and costs. Chen et al. (2016) examine extensive data on the impact of UMP spillovers on key economic variables for several Latin American countries provides evidence that spillovers had a greater impact on financial and economic variables in Brazil, compared to AE countries, which is consistent with Brazil's vulnerable characteristics: Following a cut in US corporate spreads, appreciation pressure rose substantially for Brazil. This might be attributed to the Brazilian currency being a traditional carry-trade investment currency (Bowman, Londoño, and Sapriza 2015). Furthermore, a risk-on effect led to capital inflows into Brazil, leading to higher equity prices. The increase in equity prices was larger than in other Latin American countries which demonstrates that Brazil is focus to foreign investment. While Argentina loosened monetary policy, Brazil and Mexico tightened their policy rate in response to lower corporate spreads, likely to prevent hyperinflation. Consequently, in contrast to Argentina, Brazil experienced negative inflation, despite recording positive real GDP growth (Chen et al. 2016).

An increase in real GDP growth would suggest that Brazil profited to some extent from QE. However, to understand the complex effects of QE, it is necessary to analyse the time-varying effects of spillovers onto Brazil. Chen et al. (2016) find that QE1 likely supported the Brazilian recovery from 2009. Interestingly, while there was an initial capital outflow at the start of QE1, aligning with the findings of Fratzscher, Lo Duca, and Straub (2018), the effect reversed rapidly, and capital inflows in Brazil rose during QE1. Consequently, foreign monetary policy contributes to Brazil's market volatility, aligning with the findings of Apostolou and Beirne (2019). This might have also led to Brazil's high exchange rate volatility (Chen et al. 2016). Whereas QE1 occurred in times of recession and helped the economy to recover, QE2 occurred at the peak of Brazil's real GDP growth which suggests that QE2 potentially contributed to Brazil's overheating. Brazil's growth may have accelerated more rapidly than in other countries due to looser monetary and credit conditions, as evidenced by increased money and credit growth. After QE2, real GDP reached its peak and subsequently decreased, including during the maturity extension program in the US, a program where shorter-term Treasury securities were sold to buy longer-term Treasury securities. Finally, real GDP growth rebounded during QE3, indicating that QE3 might have played a role in preventing a recession in 2012 (Chen et al. 2016). However, the FED announcement of tapering, meaning a withdrawal from their stimulus program in May 2013, led to capital outflows out of Brazil which resulted in currency depreciation and ignited fears of a recession (Mohan and Kapur 2014). This analysis highlights Brazil's vulnerability to spillover effects, resulting in significant fluctuations in key economic variables. Considering that Brazil is a major exporter of commodities, policy measures affecting the economy could lead to spillback effects onto EMEs and AEs by affecting commodity prices (International Monetary Fund 2016; Mwase, et al. 2016). Finally, previous studies may have even underestimated the extent of UMP spillovers due to the presence of non-linear spillovers, particularly through asset prices (Dou et al. 2020).

3 Commodity Price Swings and Monetary Policy Spillovers in a DSGE Framework

The previous section demonstrates that monetary policy spillovers can have deleterious consequences for EMEs. Considering increases in the volatility of commodity prices, commodity-reliant EMEs become increasingly vulnerable to spillover effects (Kilian 2009). Filardo's DSGE model conceptualizes the effects of commodity price swings to find an adequate policy reaction to stabilise the economy, thereby limiting spillovers (Filardo et al. 2018). This section presents the baseline model of Filardo et al. (2018) and analyses its implications for commodity price shocks and spillovers based on their model simulations. Therefore, the section aims to convey an understanding of how the baseline model is constructed and how it can be used to analyze monetary policy decisions and their consequences on the economy. This will be important in the subsequent section, where the underlying model is further explored through additional model simulations and adapted with respect to the monetary rule in section 4.2.

The model is based on a multi-country DSGE model introduced by Nákov and Pescatori (2010) and differentiates between commodity-exporting countries (CECs) and a commodity importing country (CIC), albeit the latter can also be interpreted as a region of countries. Unlike the underlying model, Filardo et al. (2018) employ a broad basket of commodities instead of just oil to enhance generality. The main assumptions of the model are market clearing, cross-border financial autarky and a common currency to simplify the analysis. The basic setup of the model consists of the households maximising their utility function over consumption and labour while having a standard budget constraint. The optimal path of consumption has the form of a standard Euler equation. A higher real interest rate will lower consumption in the current period relative to the next period since saving becomes more attractive to maximise overall consumption. Consumption, in turn, is defined by Filardo et al. (2018) as a Cobb-Douglas function (Cobb and Douglas 1928) of final goods consumption and commodity demand of the households. Therefore, they expand the model by introducing a commodity good in the household's utility function. This definition is crucial because the presence of a commodity good in the utility function can cause a disparity between headline and core inflation in the CIC. In turn, monetary policy has to decide whether it should focus on headline inflation and fully lean against a shock or focus on core inflation and look through the first round of shock effects in the case of a supply shock. The CIC also uses commodities to produce final goods and sells them to the CECs whose household's utility depends on final goods consumption. Final goods producers act under monopolistic competition and only use commodities and labour as inputs. They buy commodities at the real commodity price which is the commodity price relative to the aggregate price. In the model of Filardo et al. (2018), final good producers set the prices assuming staggered price mechanisms in the style of Calvo (1983), which implies nominal rigidities inherent to DSGE models. In contrast, CECs have no nominal rigidities and consist of a dominant commodity exporter and a small group of competitive exporters (Filardo et al. 2018). Their commodity production function depends on a productivity factor, which evolves exogenously, and the amount of intermediate goods (i.e., final goods) bought from the CIC. Changes in productivity are seen as a global commodity supply shock. If the market is perfectly competitive, commodity prices are equal to marginal costs. In contrast, if there is a dominant player active, the dominant exporter sets its price to maximise the expected present discounted value of the logarithm of profits. An important difference from the underlying model is that the dominant commodity exporter does not internalise the feedback of its decisions on macroeconomic variables of the CIC including marginal cost, output, consumption, price dispersion and the total mass of competitive fringe countries. Therefore, the model implies a more restrictive information availability, which can be seen as realistic within a world of information asymmetries. Consequently, the maximisation problem of the dominant exporter determines the real commodity price as a markup over marginal cost:

$$\mathrm{Q_t} = \Psi_{\mathrm{t}} \mathrm{Z_t}^{-1}, \tag{1.1}$$

with $\Psi_t \equiv 1/(1-\eta_t)$being the commodity market markup and $\eta_t = \mathfrak{M}_t/(\mathfrak{M}_t + 2X_t)$ representing the elasticity of ubstitution of net global demand.[4] Different from most DSGE models, commodity prices are modelled as endogenously changing, being driven by supply and demand shocks, which allows for an analysis of an optimal policy response depending on the shock origin. Marginal costs of the CEC, Z_t^{-1}, are driven by global commodity supply shocks like productivity shocks. In contrast, a markup shock can be interpreted as a demand shock, signaling a shift in agents' preferences towards commodity consumption, although firm-specific supply shocks, like an increase of market share of the dominant exporter, can also induce markup shocks. To consider the optimal monetary policy reaction to shocks, Filardo et al. (2018) assume a linear Taylor rule determined by deviations in output, interest rate and inflation from their benchmarks. In this model, monetary policy decisions are made only from the perspective of the CIC. Filardo et al. (2018) predominantly focus on efficient output but introduce natural output. The comparison between natural and efficient output highlights that, unlike for natural output, stabilising efficient output and core inflation is not immediately achievable after commodity price shocks, implying spillovers. Natural output is the level of output consistent with a flexible price equilibrium. In contrast, the level of efficient output requires no monopolistic distortions in commodity and final goods markets and flexible prices.

Therefore, the efficient output gap is the difference between actual output and the efficient level of output which can be expressed as:

$$\hat{\mathscr{Y}}_t^{e} = \hat{\mathscr{Y}}_t^{n} - \left(\frac{\alpha}{1-\alpha} - \frac{1}{1+\upsilon}\frac{\gamma}{1-\gamma}\Upsilon \right)\psi_t - \frac{1}{1+\upsilon}\frac{\gamma}{1-\gamma}(\Upsilon - \Upsilon^e)\, z_t. \quad (1.2)$$

Hence, the efficient output gap depends on the natural output gap[5], on ψ_t being the commodity markup deviation from the steady state and z_t as a productivity shock[6]. Therefore, demand and supply shocks both affect $\hat{\mathscr{Y}}_t^{e}$. Additionally, the formula implies that deviations in ψ_t or z_t lead to deviations between $\hat{\mathscr{Y}}_t^{e}$ and $\hat{\mathscr{Y}}_t^{n}$. Specifically, ψ_t counteracts the effects of a demand shock through an increase in markup. This is because efficient allocation implies that fluctuations in commodity markup do not affect the level of efficient output. Moreover, a negative supply shock would lead to an efficient and natural output gap, albeit the gap would be smaller in the efficient case which affects the efficient interest rate response

4 $\mathfrak{M}_t$ is the commodity production of the dominant exporter and X_t is the supply of the fringe.

5 $\hat{\mathscr{Y}}_t^{n} = \left(\frac{\alpha}{1-\alpha} - \frac{1}{1+v}\Upsilon\right)mc_t$ with mc_t denoting the deviations in marginal cost in period t.

6 $\Upsilon \equiv \left[1 - \frac{\alpha}{\mu}Q^{\gamma/(1-\gamma)}\right]^{-1} \geq 1$ and $\Upsilon^e \equiv \left[1 - \alpha Z^{-\gamma/(1-\gamma)}\right]^{-1}$. Υ and Υ^e are only equal under perfect competition or if commodities are only consumed ($\alpha = 0$).

to a supply shock, later shown in formula (1.5).

Furthermore, monetary policy can focus on stabilising headline or core inflation which are defined, respectively, as follows:

$$\pi_t = \pi_{Y,t} + \frac{\gamma}{1-\gamma}\Delta q_t \tag{1.3}$$

$$\pi_{Y,t} = \kappa_y \hat{\mathscr{Y}}_t^{\,e} + E_t\pi_{Y,t+1} + u_t. \tag{1.4}$$

Core inflation is a Phillips curve determined by expected core inflation, an endogenous cost-push shock, u_t, and the efficient output gap with κ_y as a scaling factor. Furthermore, u_t is a function of markup and productivity, implying that both demand and supply shocks directly affect core inflation. Contrary to other models, the model of Filardo et al. (2018) implies that stabilising the efficient output gap and core inflation is no longer possible due to this Phillips curve. An increase in commodity price markup puts upward pressure on core inflation. However, the increase in commodity price markup lowers the efficient output gap as shown in formula (1.2). Therefore, monetary policy cannot immediately stabilise the economy, implying more persistent spillovers within a region of CICs. In this efficient benchmark, monetary policy focuses on the efficient interest rate where final goods and commodity markets are perfectly competitive:

$$r_t^{\,e} = (g_t - E_t g_{t+1}) - (\mathscr{Y}_t^{\,e} - E\mathscr{Y}_{t+1}^{\,e}) - \frac{\gamma}{1-\gamma}(\Upsilon^e - 1)(z_t - E_t z_{t+1}). \tag{1.5}$$

The formula implies that $r_t^{\,e}$ does not respond to markup changes since they do not affect the efficient output. A negative supply shock would decrease the efficient interest rate but less than the natural rate because it does not incorporate the decrease in markup. As a result, monetary policy leans more against this commodity price shock following the efficient benchmark, thereby increasing the efficient output gap while lowering core inflation and inhibiting immediate economic stabilisation. Similarly, for a positive exogenous demand shock, the increasing commodity price markups would prolong the process of economic stabilisation. Turning to the monetary policy rule, Filardo et al. (2018) focus on the efficient benchmark policy rule which is defined as:

$$r_t = E_{t\,|\,t-1}\left[r_t^{\,e} + \varphi_{core}\pi_{Y,t} + \varphi_{\mathscr{Y}}\hat{\mathscr{Y}}_t^{\,e}\right] + \varphi_{com}\,\Delta\, q_t. \tag{1.6}$$

Here, φ_{core} is the weight on core inflation, $\pi_{Y,t}$, $\varphi_{\mathscr{Y}}$ the weight on the efficient output gap, $\hat{\mathscr{Y}}_t^{\,e}$, and φ_{com} the weight on the change in commodity price, Δq_t. To find the optimal weights on these variables, the model compares policy rules by analysing their effect on welfare, whereas welfare encompasses a combination of utility and the discounted welfare of the next period. Filardo et al. (2018) suggest that different welfare losses arise for policy rules that respond only to core inflation compared to those that respond only to headline inflation, with the former generating fewer and the latter resulting in larger losses. This is because policy rules targeting core inflation account for commodity price effects, resulting in less volatile interest rates and, consequently, more optimal outcomes. Looking at demand and supply shocks illustrates the meaning of the model of Filardo et al. (2018), compared to standard DSGE models, and the issue for the monetary authority. An exogenous shift in aggregate demand demonstrates that, different from typical DSGE models, a change in the interest rate will not completely offset the shock and a positive output gap remains for approximately six quarters, due to the nature of the shock. In this scenario, monetary authorities ought to internalise monetary policy spillovers across borders and coordinately lean against the shock to reduce procyclical movements and bolster economic stabilisation. Similar to a demand shock, monetary authority cannot immediately offset a commodity supply shock. However, different from a demand shock, the macroeconomic impact is comparably modest. Therefore, monetary policy ought to look through commodity supply shocks.

Importantly, the model expands on typical models by accounting for the risk of misdiagnosing the origin of a commodity price shock resulting in adverse monetary policy spillover effects because of the suboptimal policy responses. This risk arises because monetary authority cannot determine the type of shock in real time due to a lack of information. Since a supply shock affects the efficient output whereas a demand shock would not, determining the output gap and the interest rate to close the gap is arduous. Hence, Filardo et al. (2018) implement a Kalman filter (Kalman 1960) of the form:

$$\mathrm{E_t}^{\mathrm{ma}} \lfloor \mathrm{z_t} \ \psi_{\mathrm{t}} \rfloor' = \mathrm{Mq_t}, \tag{1.7}$$

to represent how the monetary authority deduces the sources of commodity price fluctuations, based on past data. M is a weighted average of the covariances and variances of ψ_t and z_t. M is calculated as follows:

$$\mathrm{M} = \frac{\mathrm{x}}{\mathrm{x}^2 - 2\rho\mathrm{x} + 1} \begin{bmatrix} \rho - \mathrm{x} \\ \frac{1}{\mathrm{x}} \quad - \rho \end{bmatrix}, \tag{1.8}$$

with $\rho = \mathrm{corr}(\mathrm{z_t}, \psi_{\mathrm{t}})$ and $\mathrm{x} = \sigma_\psi / \sigma_\mathrm{z}$. Filardo et al. (2018) analyse three misdiagnosis cases. Firstly, if a supply shock is mistaken for a demand shock (misdiagnosis case A). Secondly, if a demand shock is mistaken for a supply shock (misdiagnosis case B). Finally, in misdiagnosis case C, monetary authority attributes commodity price fluctuations partially to both types of shocks, even though the fluctuations are caused by only one of them. In misdiagnosis case A, x converges to 0 due to a high supply shock volatility, relatively speaking. Since in the past, commodity price fluctuations were caused by demand shocks, monetary authority attributes nearly all the fluctuations to the commodity price markup, mistaking the supply shock for a demand shock: If $\mathrm{x} \rightarrow 0,\ \mathrm{E_t}^{\mathrm{ma}}\left[\mathrm{z_t}\ \psi_{\mathrm{t}}\right]^{'} \rightarrow \left[0\ \mathrm{q_t}\right]^{'}$. Therefore, monetary policy will increase interest rates too harshly, leading to an immense drop in inflation and output. In misdiagnosis case B, monetary authority wrongly attributes all the fluctuations to productivity: If $\mathrm{x} \rightarrow \infty,\ \mathrm{E_t}^{\mathrm{ma}}\left[\mathrm{z_t}\ \psi_{\mathrm{t}}\right]^{'} \rightarrow \left[-\mathrm{q_t}\ 0\right]^{'}$. Mistaking a demand shock for an exogenous supply shock leads to a look-through policy, causing spillover and spillback effects, in the sense that the policy reaction contributes to procyclicality within the region of CICs. In misdiagnosis case C, monetary authority attributes fluctuations partially to both, markup, and productivity, with weights dependent on the relative volatility and correlation of the components. In this case, monetary authority would respond excessively to supply shocks and inadequately to demand shocks. Finally, Filardo et al. (2018) suggest that monetary authority should, under the risk of misdiagnosis, focus on core inflation since it stabilises the economy more actively. As a result, monetary policy would lean against a demand shock, reducing spillover effects, while limiting the risk of responding too harshly to a supply shock. Nonetheless, the policy response cannot immediately stabilise the economy under the risk of misdiagnosis. To improve the accuracy of monetary policymaking, the monetary authority tries to learn about the origin of a shock by analysing previous data and continuously updating its assessment via information about the economy's response to monetary policy actions. The learning process over time shows that impulse responses lead to convergence with the full information impulse responses. This is because, over time, monetary authority learns about the misdiagnosis and adapts its policy response. Consequently, the interest rate response is between the misdiagnosis case and the optimal policy response. Therefore, if, at first, a demand shock is misdiagnosed, this learning process would lead to an adaption of the policy reaction with interest rates increasing, thereby reducing procyclicality. However, the process cannot completely offset the initial mistake. Therefore, the learning process may be constrained by only observing the macroeconomic consequences of policy actions.

Finally, Filardo et al. (2018) suggest that, in a world of incomplete monetary policy cooperation, there is an incentive to deliberately misdiagnose the nature of a shock due to the domestic mandate of central banks. Especially smaller countries with a smaller impact on the global situation would be prone to treat shocks as purely exogenous because they ignore the impact of their policy decisions abroad. Additionally, the first mover advantage reinforces the likelihood of a suboptimal behaviour of the whole group. Each country in the same situation has an incentive to deviate. Therefore, central banks collectively neglect spillover and spillback effects of their decisions, leading to procyclicality. Consequently, central banks should enhance policy cooperation according to Filardo et al. (2018).

4 Model Simulations

4.1 The Effect of Monetary Policymaking in a DSGE Framework

Filardo et al. (2018) suggest to internalise monetary spillover and spillback effects and fully lean against a demand shock while looking through a supply shock. This section simulates the reactions of key variables to specific supply and demand shocks within the MMB, a model comparison platform (Wieland et al. 2012; Wieland et al. 2016). At first, a positive aggregate demand shock will be analysed via a positive fiscal policy shock. Afterwards, a negative supply shock through a decrease in productivity will be simulated. This section will show the responses of variables which are crucial to understand the shock propagation, particularly interest rate, core inflation, output, commodity price, marginal costs, and aggregate consumption. First, these simulations provide an understanding of the propagation of fiscal policy and productivity shocks within the model and explore monetary policy reactions and their implications for limiting spillovers. Second, analysing these shocks lays the foundation for scrutinizing the policy suggestions of Filardo et al. (2018). In particular, analysing a fiscal policy shock as a demand shock, an approach not explored by Filardo et al. (2018), outlines implications for monetary policy decisions. Section 4.2 explores this further, where the baseline monetary policy rule proposed by Filardo et al. (2018) is compared to a policy rule with inertia in its responsiveness to shocks. The model is tested given the suggested weights of $\varphi_{\text{core}} = 1.5$, $\varphi_{\mathscr{Y}} = 0.5$ and $\varphi_{\text{com}} = 0.05$ in the policy rule and the predetermined calibration of structural parameters of Filardo's model in the MMB (Filardo et al. 2018; Wieland et al. 2012; Wieland et al. 2016). The policy rule is modelled according to formula (1.6) with monetary authority forming expectations of core inflation and output in the current period, based on their values in the previous period, since they cannot observe their changes in real-time.

The simulation presented in Figure 1 shows the responses of key variables within the CIC to a positive aggregate demand shock in the form of a fiscal policy shock with government spending increasing by one percent.

Figure 1: Response to a Positive Aggregate Demand Shock for the Commodity Importing Country

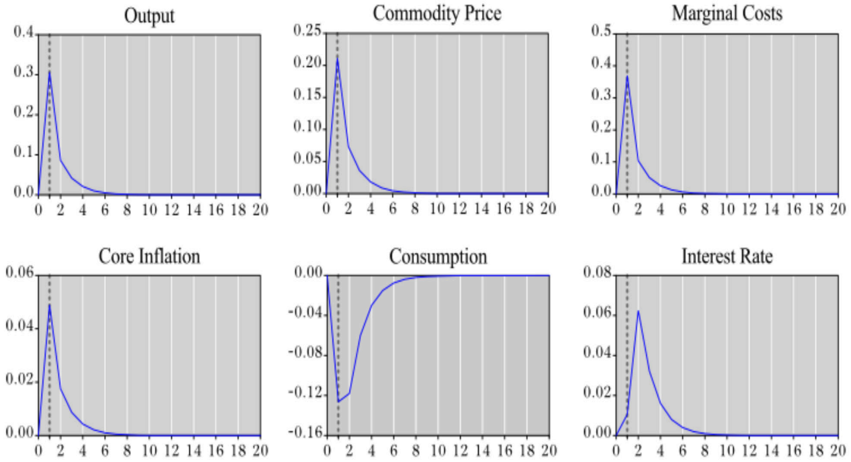

Fig. 1 Impulse responses in percentage points (y-axis) over a horizon of 20 periods (x-axis) to a positive aggregate demand shock, under the efficient benchmark, using the standard Taylor rule (1.6). The shock is calibrated to generate a 1% increase in government spending. The dotted grey line marks period 1.

The propagation of the shock in period 1 is as follows. Starting in the steady state, an increase of government spending leads to higher aggregate demand for final goods, boosting final goods production and thus output. Therefore, final goods producers demand more commodities as an input for production, allowing the dominant exporter to increase its markup, which then leads to an increase in commodity prices. Furthermore, to meet this higher aggregate demand, final goods producers employ more workers, resulting in higher real wages. As a result of higher commodity prices and higher real wages, marginal costs for the CIC increase. Looking at formula (1.4), the process of shock propagation leading to higher core inflation is depicted by a positive efficient output gap, an endogenous cost-push shock through the higher markup from the CEC and higher expected core inflation. Since the preference of the households towards consumption remained unchanged, their consumption decreases following the higher final goods and commodity prices, aligning with a crowding-out effect of consumption through fiscal policy (Cwik and Wieland 2010). Furthermore, the interest rate increases in period 1 due to the increase in commodity prices. However, monetary policy does not fully lean against the shock in period 1 because it cannot perceive the current changes in output and inflation. Therefore, the interest rate reaches its peak in period 2, adapting the expectations to the former rise of output and core inflation. Thus, the monetary authority fully leans against the shock in period 2, putting downward pressure on these variables. However, another crucial change occurred from period 1 to period 2. The government spending, which was a one-time shock in period 1, decreases and reaches its initial level in period 2. Consequently, total aggregate demand falls. This in turn leads to a lower final goods production and depresses output in period 2. As a consequence, commodity demand decreases which leads to a reduction in markup and subsequently lower commodity prices. Together with the lower labour demand, the decrease in commodity prices results in lower marginal costs. Furthermore, core inflation contracts following lower markup and a lower output gap. The lower prices outweigh the higher interest rate in period 2 and make consumption more attractive, leading to a mild increase in consumption. Therefore, all key variables except for consumption and interest rate decrease substantially from period 1 to period 2. In the subsequent periods, interest rates gradually decrease but stay above zero until output and core inflation converge to their steady state. The decreasing prices and interest rates also lead to a recovery of consumption. Therefore, the shock fades away and all the key variables return to their initial levels after approximately 8 periods.

This shock demonstrates that monetary policy is not able to immediately stabilise the economy, implying more persistent spillovers. Furthermore, the policy reaction might be suboptimal for this shock. Since the demand shock was not caused by a change in preferences, but by a one-time change in government spending, a milder policy response might have been more appropriate to limit the drop in household consumption, which, together with the decrease in government spending in period 2, might have stabilised output and core inflation more aptly. This hypothesis will be analysed in the next section.
For a negative supply shock through a decrease in productivity by one percent, the impulse responses are shown in Figure 2.

Figure 2: Response to a Negative Supply Shock for the Commodity Importing Country

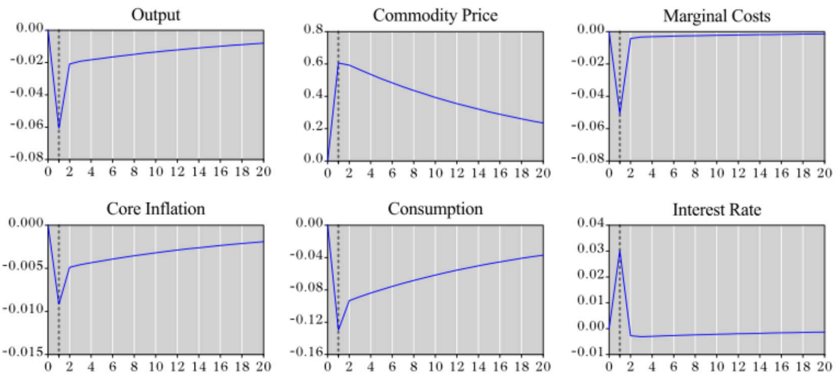

Fig. 2 Impulse responses in percentage points (y-axis) over a horizon of 20 periods (x-axis) to a negative supply shock, under the efficient benchmark, using the standard Taylor rule (1.6). The shock is calibrated to generate a 1% decrease in productivity. The dotted grey line marks period 1.

Starting in the steady state, a decrease in productivity leads to an increase of marginal costs of the commodity exporter in period 1. Subsequently, commodity production decreases. The lower supply and higher marginal costs of the commodity exporter then induce an increase in the commodity price. Furthermore, since the preference towards consumption did not change, the hike in prices, which together with higher interest rates implies a higher real interest rate, leads to a decrease in aggregate consumption of the households. Households rather save and consume later once prices are brought down again. The effect on marginal costs for the CIC is multi-faceted. A higher commodity price contributes to increasing marginal costs of the final goods producer buying commodities for production. However, this effect is being offset by the decrease in real wages. Real wages decrease following lower consumption and higher labour supply. Labour supply increases because of a negative income effect due to the higher commodity prices. Consequently, marginal costs of the CIC decrease. Overall, the increase in commodity prices and decrease in consumption outweigh the minor increase in labour, leading to a decrease in output which reaches its nadir in period 1. Following the negative efficient output gap, core inflation decreases, albeit only slightly due to the moderate magnitude of the shock and the partially offsetting effect of lower productivity of the CEC which increases marginal costs for the CIC. In period 1, the role of monetary policy is negligible. As monetary authority solely observes the increase in commodity prices, but has little weight on commodity price changes, interest rates marginally increase. However, after observing the decrease in core inflation and output, interest rates sharply decrease in period 2 and converge to the steady state in subsequent periods. Consequently, the lower interest rates increase consumption. In turn, the higher consumption increases production, thereby boosting real wages and thus marginal costs. Subsequently, output increases in period 2. Since output and productivity rise, core inflation also increases in period 2. At the same time, commodity prices only slowly decrease due to the low policy rate and associated higher commodity demand. Finally, due to the nature of the shock with productivity only slowly recovering, the mild policy response and the associated slow decrease in commodity prices, the recovery of variables like core inflation and output after period 2 takes longer than for the fiscal shock and is not complete within the 20-period horizon.

The responses to a supply shock underpin the importance of correctly identifying the origin of a shock. With the mild response of monetary policy, key variables do not witness extreme fluctuations and gradually return to their steady state, thereby potentially limiting spillovers.

4.2 How Different Policy Rules Shape Economic Fluctuations and Spillovers

Achieving less volatile policy reactions and economic stabilisation, thereby reducing monetary policy spillovers, would be highly desirable. Therefore, this section addresses two questions. First, whether policy rules other than the standard Taylor Rule (STR) used by Filardo et al. (2018) can lead to a smoother and less volatile policy reaction while limiting economic instability. Second, this section analyses whether the recommendation to fully lean against a demand shock is valid or if it is suboptimal in the case of a fiscal policy shock and therefore a narrower classification of the origin of different types of shocks necessary. Here, I will introduce the inertial Taylor rule (ITR). In contrast to the STR, the ITR responds more slowly to shocks. The ITR crucially exhibits inertia by including a lagged federal funds rate. Any change in the current policy rate signals a longer-lasting change in the policy stance (Carlstrom and Fuerst 2008). The ITR is an intriguing object of scrutiny due to its benefits and costs that have major implications for monetary policy spillovers and the ITR's real-world applicability. There is empirical evidence that the ITR has a better historical tracking performance and is closer to the actual decisions of the FED (Carlstrom and Fuerst 2008). The STR might be more suitable for quickly stabilising economic activity and inflation due to its aggressive response. However, the ITR might be chosen over the STR to avoid high interest rate volatility, as a hedge against uncertainty and to ensure economic and financial stability, according to Carlstrom and Fuerst (2008). They find that after a commodity price shock, the promise of higher interest rates in the future keeps inflation lower than in the non-inertial case under price and wage stickiness. The model of Filardo et al. (2018) solely includes price stickiness, making the outcome of the comparison ambiguous. For the comparison of inertial and standard rule, I modelled the ITR as follows:

$$\mathrm{r_t} \ = \ 0.7\mathrm{r_{t-1}} \ + 0.3\left\{\mathrm{E_{t\,|\,t-1}}\left[\mathrm{r_t}^{\mathrm{e}} + \ \varphi_{\mathrm{core}}\pi_{\mathrm{Y,t}} + \varphi_{\mathscr{Y}}\hat{\mathscr{Y}}_{\mathrm{t}}^{\mathrm{e}}\right] \ + \varphi_{\mathrm{com}}\,\Delta\,\mathrm{q_t}\right\}. \quad (2.1)$$

The weights on commodity prices, core inflation and output are set equal for both policy rates. Furthermore, the degree of inertia corresponds to a weight on the lagged federal funds rate of 0.7, aligning with the range of inertia found by empirical literature (Clarida, Galí, and Gertler 1999). At first, the responses to a positive aggregate demand shock under both policy rules will be compared. Afterwards, the responses to a negative supply shock will be examined. The first simulation in Figure 3 displays the response to a positive aggregate demand shock, in the form of a positive fiscal policy shock, under the STR (blue line) and ITR (red line).

Figure 3: Response to a Positive Aggregate Demand Shock Under Different Policy Rules for the Commodity Importing Country

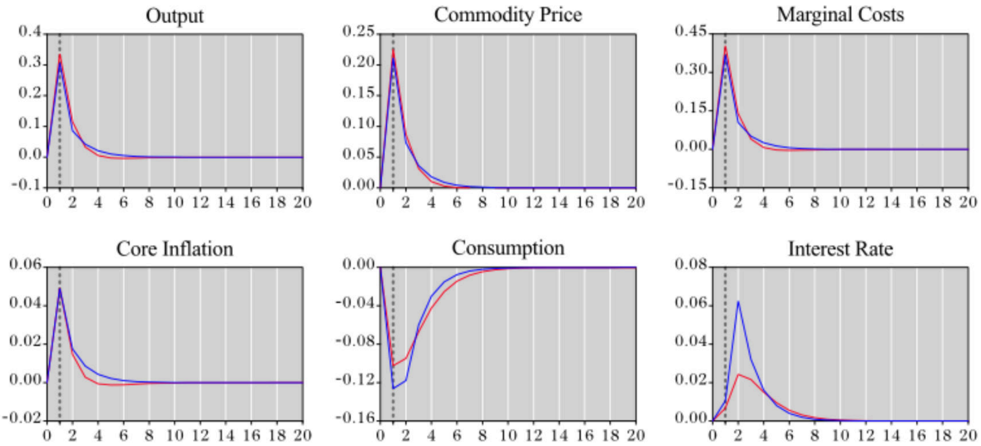

Fig. 3 Impulse responses in percentage points (y-axis) over a horizon of 20 periods (x-axis) to a positive aggregate demand shock, under the efficient benchmark, using the standard Taylor rule (1.6) (blue line) and the inertial Taylor rule (2.1) (red line). The shock is calibrated to generate a 1% increase in government spending. The dotted grey line marks period 1.

Comparing both policy rules, one can deduce that the lower interest rate volatility of the ITR leads to a faster stabilisation of core inflation, reaching its initial state around period 4, whereas it takes core inflation until period 7 in the STR case to stabilise. The same accounts for the commodity price which stabilises approximately 2 periods prior to the standard case. Likewise, output in the inertial case decreases faster from its peak, leading to a lower output than in the STR case after period 3. Consumption decreases in both cases but due to the lower interest rate in periods 1 and 2, households have more incentive to consume more in period 1 following the inertial rule. However, consumption recovers more slowly in the ITR scenario since the interest rate decreases less after period 2 than in the STR case. Although the ITR leads to a slightly higher peak of key variables in period 1, due to the lower interest rate, the ITR achieves a faster recovery of key variables like core inflation and output than the STR does. This has intriguing implications. Especially in a real-world context, where strong changes in interest rates cause adverse spillovers, this finding is pivotal and could imply that monetary policy spillovers can be limited while achieving monetary policy objectives more effectively.

Contrary to a fiscal policy shock, monetary policy in the STR case looks through a supply shock, as shown in Figure 4, leading to less substantial differences between both policy rates.

Figure 4: Response to a Negative Supply Shock Under Different Policy Rules for the Commodity Importing Country

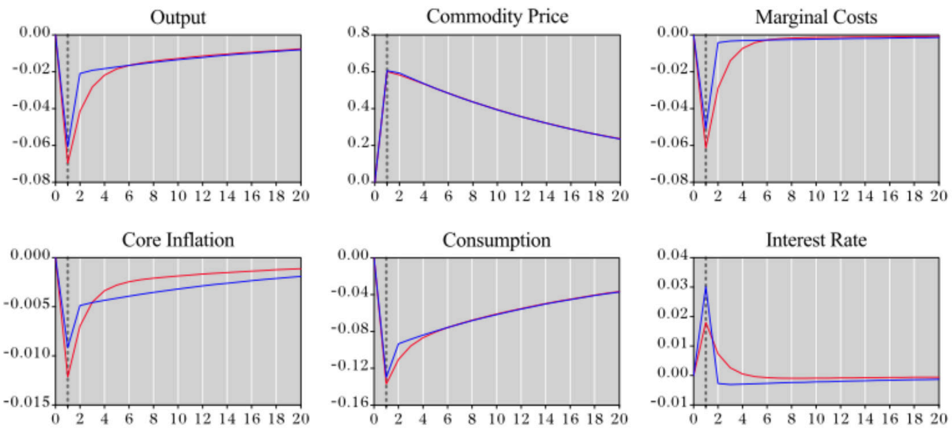

Fig. 4 Impulse responses in percentage points (y-axis) over a horizon of 20 periods (x-axis) to a negative supply shock, under the efficient benchmark, using the standard Taylor rule (1.6) (blue line) and the inertial Taylor rule (2.1) (red line). The shock is calibrated to generate a 1% decrease in productivity. The dotted grey line marks period 1.

Overall, the policy rate following the ITR increases less than in the STR case in period 1 but stays above zero for a longer time. This leads to an initially stronger decrease in output, consumption, and core inflation in the ITR scenario because forward-looking households save to profit from positive interest rates from periods 1 to 4 rather than consume. Since consumption is lower in the inertial case than in the standard case, output decreases more in period 1. Lower output then leads to core inflation decreasing more in period 1 in the ITR case. In the second period, the policy rate following the STR heavily decreases, whereas the decrease of the inertial policy rate is less substantial. In contrast to the fiscal shock scenario, the STR policy rate is already lower than the ITR policy rate in period 2. Therefore, the fast response to lower output and core inflation of the STR contributes to a fast recovery of these variables in period 2. From period 3 on, however, core inflation and output in the inertial case recover at a faster pace, and core inflation following the ITR is higher than for the STR, because policy rates in the ITR case still decrease, whereas the STR policy rate increases again. In the subsequent periods, the differences between both cases diminish, due to the convergence of both policy rates. However, looking at the magnitude of the shock in period 1 and the recovery in period 2, the STR seems to perform better in a supply shock scenario, compared to the ITR.

In conclusion, the shocks demonstrate that the ITR can lead to a less volatile policy reaction, although its effectiveness at limiting economic instability depends on the type of shock. Therefore, assessing the specific source of a shock is crucial for the optimal policy response. Furthermore, fully leaning against a fiscal shock is suboptimal. The real-world applicability and policy recommendations drawn from these findings will be discussed in the following section.

5 Discussion

Throughout the previous sections, it becomes evident that various factors contribute to monetary policy spillovers which heavily affect EMEs. The exacerbation of financial risks through monetary policy spillovers poses a threat to financial and economic stability in EMEs and AEs. In this section, I propose to implement systematic measures and strategies to limit spillovers in the short and long term.

In the short term, two central measures would contribute to a reduction in spillover effects, namely increasing policy coordination to reduce procyclicality and an improvement of policy responses to different sources of shocks. First, central banks ought to go beyond their mandate and coordinate their policy reaction and, within their capabilities and optimal policy rules, collectively act against certain shocks to reduce procyclicality, as suggested by Filardo et al. (2018). However, policy coordination is difficult to achieve due to potential incentives to deviate (Filardo et al. 2018). Additionally, central banks differ in their objectives, amplifying the difficulties of policy coordination. Therefore, a neutral assessor should be implemented that bridges divergent views of national policymakers by analysing different strategies and the resulting trade-offs to reasonably judge costs and benefits for coordination (Ostry and Ghosh 2013). Second, central banks should act accordingly to different types of shocks. Here, my paper contributes to existing literature by providing a more nuanced view on optimal monetary policy actions depending on the source of a shock and hightlights the importance for monetary policy to correctly identify those sources. In particular, I argue that it is not sufficient to differentiate between supply and demand shocks, as different types of demand shocks require different policy actions, thereby expanding the findings of previous papers such as Filardo et al. (2018). To illustrate this, I compare the effects of the baseline model's policy rule to the ITR, demonstrating that not fully leaning against certain shocks and collectively reducing interest rate volatility can help mitigate economic fluctuations and adverse spillovers. Furthermore, in a real-world scenario with factors such as risk-premia, forward-looking expectations, uncertainty about shocks, currency mismatches, financial channels, and vulnerabilities of EME characteristics, investors and consumers would likely perceive high interest rate volatility and its consequences as less predictable, thereby increasing economic and financial instability. Furthermore, the risk of scarring effects should be considered when deciding on monetary policy. An overly tight policy reaction might cause a deep contraction that cannot be easily reversed with policy easing, given the sluggish rebuilding of supply during expansions (Aikman et al. 2022). Although my findings support using the ITR in a fiscal shock scenario, a robustness test for a plethora of DSGE models for this scenario, compared to empirical data, is necessary to come to a more general conclusion, since the model of Filardo et al. (2018) rests on model-specific assumptions. For fiscal policy shocks, model-specific assumptions like the extent of price and wage rigidity, financial frictions or the share of liquidity constraint consumers lead to varying fiscal multipliers, potentially resulting in different policy conclusions (Kilponen et al. 2019). Furthermore, the real-world applicability of model simulations of fiscal shocks is subject to criticism in general, because many model specifications impose tight ranges of fiscal multipliers before conditioning them on data, potentially leading to biased results (Leeper, Traum, and Walker 2017). Therefore, DSGE models ought to be improved regarding their real-world applicability. Finding optimal policy reactions to shocks in a realistic model could bolster economic stability and limit spillovers. Filardo et al. (2018) generalize and disregard aspects of real-world intricacies. The model assumes financial autarky, a common currency, and no monetary policy actions from CECs. Therefore, the model disregards spillovers through financial and exchange rate channels that, as presented in the literature review, turn out to have a substantial impact on EMEs. Disregarding these components in a DSGE model renders it unreliable in stressed periods. Therefore, allowing for the role of foreign-currency borrowing can lead to more empirically relevant spillover findings in DSGE models, resulting in an improvement of policy decision-making (Georgiadis and Jančoková 2020). Furthermore, as my findings suggest, more attention should be drawn towards finding optimal policy reactions, depending on different types of demand or supply shocks, thereby limiting spillover effects. At the same time, it is crucial to constantly update these assessments and analyse the interplay between different types of shocks within DSGE models and in a real-world scenario. Especially in a real-world scenario, shocks tend to be complex. An initial supply shock, where a looking-through policy would be optimal, might witness a stronger pass-through of core inflation, if accompanied by a sudden demand shock. This makes a fast assessment of the underlying dynamics of shocks crucial for monetary policy. The necessity of such an improvement becomes particularly lucid in recent times of the COVID-19 aftermath, where understanding the interplay of demand and supply shocks and their impact on inflation prove challenging for monetary policymaking (Thorbecke 2023).

In the long term, monetary and fiscal policy ought to conduct changes in EMEs to reduce their vulnerability, thereby structurally mitigating spillovers. The literature review shows that a financial restructuring of EMEs is crucial to reduce the amounts of dollar-denominated debt, making EMEs less vulnerable to US monetary tightening (Ahmed, Akinci, and Queraltó 2021). Furthermore, a stronger currency and floating instead of fixed exchange rates would help to minimize adverse spillover effects (Degasperi, Hong, and Ricco 2021), whereas a more credible central bank through increased independence would minimize unanchored inflation expectations (Ahmed, Akinci, and Queraltó 2021). Finally, systemic risk monitoring and a harmonization of regulations across countries could reduce spillover risks of financial instability (Engel 2016).

References

[1] Agénor, Pierre-Richard, and Luiz Awazu Pereira Da Silva. 2022. "Financial Spillovers, Spillbacks, and the Scope for International Macroprudential Policy Coordination." International Economics and Economic Policy 19 (1) (February): 79–127. https://doi.org/10.1007/s10368-021-00522-5.

[2] Ahmed, Shaghil, Özge Akinci, and Albert Queraltó. 2021. "U.S. Monetary Policy Spillovers to Emerging Markets: Both Shocks And Vulnerabilities Matter." International Finance Discussion Papers 2021 (1321) (June): 1–34. https://doi.org/10.17016/ifdp.2021.1321.
Aikman, David, Mathias Drehmann, Mikael Juselius, and Xiaochuan Xing. 2022. "The Scarring Effects of Deep Contractions." Working Paper 1043. Basel: Bank of International Settlements. https://www.bis.org/publ/work1043.pdf.

[3] Akinci, Özge, and Albert Queraltó. 2018. "Balance Sheets, Exchange Rates, and International Monetary Spillovers." Staff Report 849. New York: Federal Reserve Bank of New York. https://www.econstor.eu/handle/10419/210701.

[4] Anaya, Pablo, Michael Hachula, and Christian J. Offermanns. 2017. "Spillovers of U.S. Unconventional Monetary Policy to Emerging Markets: The Role of Capital Flows." Journal of International Money and Finance 73 (May): 275–95. https://doi.org/10.1016/j.jimonfin.2017.02.008.

[5] Apostolou, Apostolos, and John Beirne. 2019. "Volatility Spillovers of Unconventional Monetary Policy to Emerging Market Economies." Economic Modelling 79 (June): 118–29. https://doi.org/10.1016/j.econmod.2018.10.006.

[6] Arezki, Rabah, and Yang Liu. 2018. "On The Asymmetry of Global Spillovers : Emerging Markets Versus Advanced Economies." Policy Research Working Paper 8662. Washington, DC: World Bank. http://hdl.handle.net/10986/30984.

[7] Böck, Maximilian, Martin Feldkircher, and Pierre L. Siklos. 2021. "International Effects of Euro Area Forward Guidance*." Oxford Bulletin of Economics and Statistics 83 (5) (May): 1066–1110. https://doi.org/10.1111/obes.12438.

[8] Bowman, David, Juan M. Londoño, and Horacio Sapriza. 2015. "U.S. Unconventional Monetary Policy And Transmission to Emerging Market Economies." Journal of International Money and Finance 55 (July): 27–59. https://doi.org/10.1016/j.jimonfin.2015.02.016.

[9] Bräuning, Falk, and Victoria Ivashina. 2020. "U.S. Monetary Policy And Emerging Market Credit Cycles." Journal of Monetary Economics 112 (June): 57–76. https://doi.org/10.1016/j.jmoneco.2019.02.005.

[10] Bruno, Valentina, and Hyun S. Shin. 2015. "Cross-Border Banking and Global Liquidity." The Review of Economic Studies 82 (2) (April): 535–64. https://doi.org/10.1093/restud/rdu042.

[11] Calvo, Guillermo A. 1983. "Staggered Prices in a Utility-Maximizing Framework." Journal of Monetary Economics 12 (3) (September): 383–98. https://doi.org/10.1016/0304-3932(83)90060-0.

[12] Carlstrom, Charles T., and Timothy S. Fuerst. 2008. "Inertial Taylor Rules: The Benefit of Signaling Future Policy." Review 90 (32) (May/June). https://doi.org/10.20955/r.90.193-204.

[13] Chen, Qianying, Andrew Filardo, Dong He, and Feng Zhu. 2016. "Financial Crisis, US Unconventional Monetary Policy and International Spillovers." Journal of International Money and Finance 67 (October): 62–81. https://doi.org/10.1016/j.jimonfin.2015.06.011.

[14] Clarida, Richard H., Jordi Galí, and Mark Gertler. 1999. "The Science of Monetary Policy: A New Keynesian Perspective." Journal of Economic Literature 37 (4) (December): 1661–1707. https://doi.org/10.1257/jel.37.4.1661.

[15] Cobb, Charles W., and Paul H. Douglas. 1928. "A Theory of Production." American Economic Review 18 (1) (March): 139–65. https://www.jstor.org/stable/1811556.

[16] Cole, Stephen J., Enrique Martínez-García, and Eric R. Sims. 2023. "Living up to Expectations: Central Bank Credibility, the Effectiveness of Forward Guidance, and Inflation Dynamics Post-Global Financial Crisis." Working Paper 31777. Cambridge, Massachusetts: National Bureau of Economic Research. https://doi.org/10.3386/w31777.

[17] Cwik, Tobias J., and Volker Wieland. 2010. "Keynesian Government Spending Multipliers and Spillovers in the Euro Area." Working Paper 1267. Frankfurt: European Central Bank. https://doi.org/10.2139/ssrn.1705013.

[18] Degasperi, Riccardo, Seokki S. Hong and Giovanni Ricco.2021. "The global transmission of U.S. monetary policy." Working Paper 9. Paris: Sciences Po. https://www.ofce.sciences-po.fr/pdf/dtravail/OFCEWP2021-09.pdf.

[19] Dou, Winston W., Andrew W. Lo, Ameya Muley, and Harald Uhlig. 2020. "Macroeconomic Models for Monetary Policy: A Critical Review From a Finance Perspective." Annual Review of Financial Economics 12 (1) (June): 95–140. https://doi.org/10.2139/ssrn.2899842.

[20] Engel, Charles. 2016. "Macroprudential Policy Under High Capital Mobility: Policy Implications From an Academic Perspective." Journal of the Japanese and International Economies 42 (December): 162–72. https://doi.org/10.1016/j.jjie.2016.06.003.

[21] Filardo, Andrew, Marco Lombardi, Carlos Montoro, and Massimo Ferrari. 2018. "Monetary Policy Spillovers, Global Commodity Prices and Cooperation." Working Paper 696. Basel: Bank of International Settlements. https://www.bis.org/publ/work696.pdf.

[22] Fleming, J. Marcus. 1962. "Domestic Financial Policies Under Fixed and Under Floating Exchange Rates." IMF Staff Papers 9 (3) (January): 369–80. https://doi.org/10.2307/3866091.

[23] Fratto, Chiara, Brendan H. Vannier, Borislava Mircheva, David De Padua, and Helene P. Ward. 2021. "Unconventional Monetary Policies in Emerging Markets and Frontier Countries." Working Paper 2021 (014): 1–71. Washington, DC: International Monetary Fund. https://doi.org/10.5089/9781513567211.001.a001.

[24] Fratzscher, Marcel, Marco L. Duca, and Roland Straub. 2018. "On The International Spillovers of US Quantitative Easing." The Economic Journal 128 (608) (February): 330–77. https://doi.org/10.1111/ecoj.12435.

[25] Fukuda, Shin–ichi. 2018. "Impacts of Japan's Negative Interest Rate Policy on Asian Financial Markets." Pacific Economic Review 23 (1) (January): 67–79. https://doi.org/10.1111/1468-0106.12253.

[26] Georgiadis, Georgios. 2016. "Determinants of Global Spillovers From US Monetary Poicy." Journal of International Money and Finance 67 (October): 41–61. https://doi.org/10.1016/j.jimonfin.2015.06.010.

[27] Georgiadis, Georgios, and Martina Jančoková. 2020. "Financial Globalisation, Monetary Policy Spillovers and Macro-modelling: Tales From 1001 Shocks." Journal of Economic Dynamics and Control 121 (104025) (December). https://doi.org/10.1016/j.jedc.2020.104025.
Hofmann, Boris, and Előd Takáts. 2015. "International Monetary Spillovers." Quarterly Review. Bank for International Settlements: 105–118.

[28] Iacoviello, Matteo, and Gastón Navarro. 2019. "Foreign Effects of Higher U.S. Interest Rates." Journal of International Money and Finance 95 (July): 232–50. https://doi.org/10.1016/j.jimonfin.2018.06.012.

[29] International Monetary Fund. 2016. "The Growing Importance of Financial Spillovers from Emerging Market Economies". In Global Financial Stability Report, April 2016—Potent Policies for a Successful Normalization, 57-86. Washington, DC: International Monetary Fund. https://doi.org/10.5089/9781513506777.082.

[30] Kalemli-Özcan, Şebnem. 2019. "U.S. Monetary Policy And International Risk Spillovers." Working Paper 26297. Cambridge: National Bureau of Economic Research. https://doi.org/10.3386/w26297.

[31] Kalman, Rudolf E. 1960. "A New Approach to Linear Filtering and Prediction Problems." Journal of Basic Engineering 82 (1) (March): 35–45. https://doi.org/10.1115/1.3662552.

[32] Kearns, Jonathan, Andreas Schrimpf, and Fan D. Xia. 2023. "Explaining Monetary Spillovers: The Matrix Reloaded." Journal of Money, Credit and Banking 55 (6) (September): 1535–68. https://doi.org/10.1111/jmcb.12996.

[33] Kilian, Lutz. 2009. "Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market." The American Economic Review 99 (3) (June): 1053–69. https://doi.org/10.1257/aer.99.3.1053.

[34] Kilponen, Juha, Massimiliano Pisani, Sebastian Schmidt, Vesna Corbo, Tibor Hlédik, Josef Hollmayr, Samuel Hurtado, et al. 2019. "Comparing Fiscal Consolidation Multipliers Across Models in Europe." International Journal of Central Banking 15 (3) (September):

285–320. https://www.ijcb.org/journal/ijcb19q3a8.pdf.

[35] Leeper, Eric M., Nora Traum, and Todd B. Walker. 2017. “Clearing up the Fiscal Multiplier Morass.” The American Economic Review 107 (8) (August): 2409–54. https://doi.org/10.1257/aer.20111196.

[36] Miyajima, Ken, Madhusudan Mohanty, and James Yetman. 2014. “Spillovers of US Unconventional Monetary Policy to Asia: The Role of Long-term Interest Rates.” Working Paper 478. Basel: Bank of International Settlements. https://www.bis.org/publ/work478.pdf.

[37] Moessner, Richhild. 2015. “International Spillovers From US Forward Guidance to Equity Markets.” Applied Economics 47 (42) (April): 4549–60. https://doi.org/10.1080/00036846.2015.1031874.

[38] Mohan, Rakesh, and Muneesh Kapur. 2014. “Monetary Policy Coordination and the Role of Central Banks.” Working Paper 2014 (70). Washington, DC: International Monetary Fund. https://doi.org/10.5089/9781484362518.001.

[39] Morgan Stanley. 2013. “EM Currencies: The Fragile Five” Morgan Stanley Research, FX Pulse: 15. https://1library.net/document/q04w8glz-pulse-preparing-volatility-recommendations-currency-forecasts-currencies-global.html.

[40] Mundell, Robert A. 1963. “Capital Mobility and Stabilization Policy Under Fixed and Flexible Exchange Rates.” The Canadian Journal of Economics and Political Science 29 (4) (November): 475–85. https://doi.org/10.2307/139336.

[41] Mwase, Nkunde, Papa M. N’Diaye, Hiroko Oura, Franto Ricka, Katsiaryna Svirydzenka, and Yuanyan S. Zhang. 2016. “Spillovers from China: Financial Channels” IMF Spillover Notes 2016 (5) (September). https://doi.org/10.5089/9781475539486.062.

[42] Nákov, Antón, and Andrea Pescatori. 2010. “Monetary Policy Trade-Offs with a Dominant Oil Producer.” Journal of Money, Credit and Banking 42 (1) (February): 1–32. https://doi.org/10.1111/j.1538-4616.2009.00276.x.

[43] Ostry, Jonathan D., and Atish R. Ghosh. 2013. “Obstacles to International Policy Coordination, and How to Overcome Them.” IMF Staff Discussion Note 2013 (11) (December). https://doi.org/10.5089/9781484334188.006.

[44] Ouyang, Zhigang, Zhenjiang Dou, Lei Wei, and László Vasa. 2022. "Nonlinear spillover effect of US monetary policy uncertainty on China's systematic financial risks." Journal of Business Economics and Management 23 (2) (February): 364–81. https://doi.org/10.3846/jbem.2022.16065.

[45] Thorbecke, Willem. 2023. "The Impact of Monetary Policy on the U.S. Stock Market Since the COVID-19 Pandemic." International Journal of Financial Studies 11 (4) (November): 134. https://doi.org/10.3390/ijfs11040134.

[46] Tillmann, Peter. 2016. "Unconventional Monetary Policy and the Spillovers to Emerging Markets." Journal of International Money and Finance 66 (September): 136–56. https://doi.org/10.1016/j.jimonfin.2015.12.010.

[47] Tran, Thi B., and Hoang C. H. Pham. 2020. "The Spillover Effects of the US Unconventional Monetary Policy: New Evidence From Asian Developing Countries." Journal of Risk and Financial Management 13 (8) (July): 165. https://doi.org/10.3390/jrfm13080165.

[48] Walerych, Małgorzata, and Grzegorz Wesołowski. 2021. "Fed And ECB Monetary Policy Spillovers to Emerging Market Economies." Journal of Macroeconomics 70 (December): 103345. https://doi.org/10.1016/j.jmacro.2021.103345.

[49] Wieland, Volker, Tobias J. Cwik, Gernot Müller, Sebastian Schmidt, and Maik H. Wolters. 2012. "A New Comparative Approach to Macroeconomic Modeling and Policy Analysis." Journal of Economic Behavior and Organization 83 (3) (August): 523–41. https://doi.org/10.1016/j.jebo.2012.01.006.

[50] Wieland, Volker, Elena Afanasyeva, Meguy Kuete, and Jinhyuk Yoo. 2016. "New Methods for Macro-Financial Model Comparison and Policy Analysis." In Handbook of Macroeconomics, edited by John B. Taylor and Harald Uhlig, 1241–1319. North Holland: Elsevier. https://doi.org/10.1016/bs.hesmac.2016.04.004.

Bargaining for the Trees? Analyzing the Impact of Female Bargaining Power on Deforestation in Sub-Saharan Africa

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January 2024

Abstract

This paper investigates the impact of female bargaining power in deforestation rates across Sub-Saharan Africa (SSA), where women actively engage in both the exploitation and conservation of forest resources but often have limited control over these resources. Utilizing the legal variations and colonial origins of national borders, the study employs spatial regression discontinuity (RD) analysis to assess these impacts. Contrary to expectations, the findings reveal that common law countries, characterized by lower female bargaining power, exhibit lower deforestation rates compared to civil law countries. These results suggest the existence of compensatory behaviors in decision-making processes related to deforestation in SSA.

1 Middlebury College. I would like to thank my advisor, Professor Erick Gong, for his advice, guidance, and support throughout the thesis process and Will Hegman for his incredible help with the data collection. I am grateful to my family and friends for being consistent sources of support. I also want to thank my thesis class for the supportive community and environment. Please refer to the replication package for instructions on how to reproduce this analysis. The findings, interpretations, and conclusions expressed in this paper are entirely mine. All errors are my own. Please send correspondence to hmaalim@middlebury.edu.

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1 Introduction

Forests play an important role in mitigating the effects of climate change by absorbing atmospheric carbon dioxide and transforming it into living biomass. This process positions forests as vital carbon sinks that also influence atmospheric moisture and rain patterns through evapotranspiration (Brack 2019, Chen et al. 2021, Pan et al. 2011, Sheil and Daniel 2009). Additionally, forests help regulate water flow aiding in flood prevention (Sanjou, Okamoto, and Nezu 2018). However, the steady decline of forest cover in Sub-Saharan Africa (SSA) jeopardizes these functions[2], diminishing the region's resilience against climate change (Igini 2022). Deforestation also exacerbates the climate crisis by halting the carbon absorption process and releasing stored carbon via burning or decomposition (Brack 2019)[3]. Moreover, tree removal leads to soil degradation, including compaction, erosion, reduced water infiltration, and increased runoff, thereby increasing flood risks (Greenpeace Africa 2024). Financially, deforestation impacts potential revenue streams like carbon credits[4], as forests gain more economic value in carbon markets.

The causes of deforestation are widely studied and are typically categorized into direct and underlying factors (Kanninen et al. 2007). Direct causes are those immediately linked to the act of clearing land, such as agricultural expansion, mining activities, wood extraction, and infrastructure development. On the other hand, underlying causes are broader societal factors that drive these direct actions. These include macroeconomic elements like economic growth or increases in agricultural rent, as well as governance-related factors such as property rights, law enforcement, and levels of corruption[5]. This paper contributes to this extensive discourse on deforestation by exploring an additional underlying cause: female bargaining power. The underlying hypothesis suggested is that an increase in female bargaining power will lead to a reduction in deforestation rates. This expectation is based on women's unique knowledge of sustainability, their inclination towards environmentally friendly outcomes, and the disproportionate impact that deforestation has on their lives.

2 According to World Bank Open Data, the proportion of forested land in SSA has decreased from 29.7% in 2000 to 26.3% in 2020. Furthermore, the continent experienced the highest global net loss of forests between 2010 and 2020, totaling 3.9 million hectares. This rate of net forest loss in Africa has been increasing each decade since 1990 (FAO 2020).

3 According to Brack (2019), approximately 12% of global greenhouse gas emissions originate from deforestation, directly contributing to the climate crisis.

4 Numerous analysts forecast that carbon credits derived from Africa's forests could become a significant export by 2050, potentially reaching around $100 billion in value (see. The Economist 2024, Mirror 2023, Le Monde.fr. 2023) while Demiralay et al. (2022) argue that including a small portion of carbon futures in a stock portfolio provides hedging benefits.

5 See: Kanninen et al. 2007, Abugre and Emmanuel 2022, Shandra 2003, Sieböck 2022, Godoy 2001, Ehrhardt-Martinez 2002, Caliskan 2013, Abman 2020.

In SSA, women heavily rely on forestry, especially in harvesting non-timber forest products (NTFPs), for their livelihood (Jimoh and Haruna 2007, Shackleton et al. 2011, Kimaro and Lulandala 2017)[6]. This reliance has led them to develop unique knowledge in the sustainable management of these vital resources. Howard-Borjas (2001) adds that this expertise is also a result of their roles as food producers and is influenced by their social positions, responsibilities, and status within their communities. Furthermore, the negative impacts of deforestation, such as increased household labor, diminished income-earning opportunities, adverse health consequences, and escalating food insecurity[7], disproportionately affect women (FAO 2024, Shandra 2008). Gender disparities also extend to environmental preferences. For example, Guarascio et al. (2013) note that while men may focus on trees for commercial purposes, women typically prefer multipurpose tree species for subsistence use, contributing to improvement of soil fertility. Additional studies have found that women prefer having more trees near their homes and a diversity of species, both to safeguard their children's health and to expand their household food supply (Gachuiri et al. 2022, Guarascio et al. 2013).

Despite their active involvement, specialized knowledge, and economic and social vulnerability, women—particularly those in rural areas—often face limited access to and control over forest resources and services (Steady 2014, Ndugwa et al. 2018). Men are typically regarded as household heads and thus more commonly perceived as legitimate knowledge holders and managers of trees and other food crops (Gachuiri et al. 2022, Akinola 2018). This gender-based exclusion from decision-making and policy formulation hinders environmental conservation efforts (FAO 2002). Nonetheless, women are not merely passive observers in these processes. At the household level, differences in outcomes and risk preferences can lead to disagreements, necessitating negotiation between women and their partners in order to make collective decisions (Bryan et al 2023). Given that increased participation of women in forest management at the community level is associated with favorable conservation outcomes (Leone 2019), I anticipate similar positive effects at the household level.

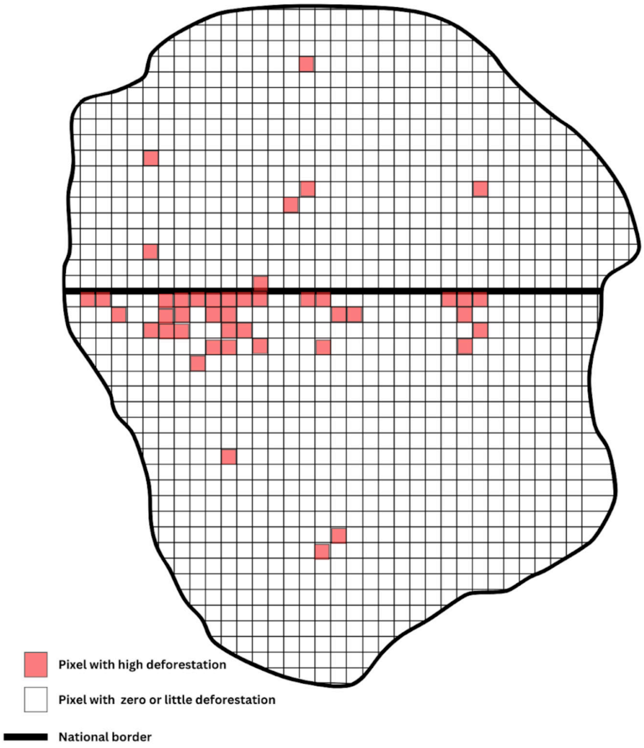
In SSA, female bargaining power varies exogenously due to legal frameworks established by European colonial powers. A key aspect of this variation is the enhanced marital property rights for women under civil law compared to common law. Civil law systems, unlike their common law counterparts, recognize women's domestic contributions, ensure joint prop-

6 Other studies also show that women living in rural forest communities are deeply involved in collecting forest products, including fuelwood, medicinal herbs, fodder for livestock, and wild food, either for personal consumption or for sale (Kiptot and Franzel 2012, Guarascio et al. 2013). It is also important to note that women contribute to agroforestry in other ways including watershed management, tree improvement, forest protection and conservation.

7 For a comprehensive summary of research papers on this topic, refer to UN WomenWatch.

erty ownership during marriage, and provide explicit protections upon marital dissolution (Anderson 2018, Hallward-Driemeier and Hasan 2012). My analysis leverages this legal variation, along with the arbitrary division of ethnic groups across different nations during the 19th century's Scramble for Africa, to examine the impact of female bargaining power on deforestation rates. These two exogenous factors create a unique research environment, allowing for consideration of both the natural environment, due to geographical proximity, and the diverse cultural characteristics of ethnic groups. This setting is ideal for exploring how female bargaining power influences outcomes like deforestation (Michalopoulos and Papaioannou 2013, Anderson 2018). Figure 1 below offer a visual representation of the methodology employed. Following the approach of Michalopoulos and Papaioannou (2013), the analysis is conducted across pixels located in the territories of ethnically split groups.

Figure 1:



Notes: I compare deforestation rates between pixels located at similar distances from the national border. This approach allows for a controlled comparison, isolating the effect of female bargaining power on deforestation. I anticipate an increase in deforestation rates when moving from areas under civil law systems to those under common law systems (from top to bottom).

The study reveals a paradoxical relationship between female bargaining power and deforestation rates. It shows that countries with common law systems, where female bargaining power is typically lower, actually experience lower rates of deforestation compared to civil law countries, which generally grant greater autonomy to women. Specifically, it finds that deforestation rates (log-transformed) in common law countries are approximately 38.61% lower than those in civil law countries, a difference that is statistically distinguishable from zero. This surprising trend might be partially explained by the "doing gender" theory (West and Zimmerman 1987). This theory suggests that individuals might engage in certain behaviors to compensate for perceived loss in their gender identity. Furthermore, the connection between legal systems and deforestation could also be affected by other variables. These include the treatment of non-profit organizations and the flexibility of judicial systems, which can influence environmental conservation. Factors like public involvement, advocacy, and legal precedents, which vary between legal systems, could play a significant role in determining how effectively a country can manage and conserve its forest resources.

This paper makes contributions to three primary areas of academic research: the determinants of deforestation (discussed above), the influence of legal origins, and the lasting impacts of colonization. This paper also adds to the extensive literature on the effects of legal traditions on various economic performance indicators, including finance ,bank ownership, labor market regulation, media ownership (see La Porta et al. 2008 for extensive summary), and female HIV prevalence (Anderson 2018). By leveraging the distinct context of SSA, it offers deeper insights into how legal origins may influence deforestation rates. Additionally, the study explores the relationship between the enduring effects of colonialism on women's bargaining power and its subsequent impact on deforestation in SSA, thereby contributing to a broader body of literature that examines similar themes (e.g., Amanor-Wilks 2009, Baten et al. 2021, Okeke 2000).

In the following section, I will provide background information that connects legal origins, female bargaining power, and deforestation. This will include the further development of the hypothesis and the presentation of a proposed causal relationship between these variables. Section III is devoted to describing the data used in this study. Then, in Section IV, I will discuss the estimation strategy in detail, focusing on the specifics of the identification design. The findings of the study will be presented in Section V. Lastly, Section VI will delve into a discussion of these findings and consider potential avenues for future research in this area.

2 Background

2.1 Legal Origin and Marital Property Rights

Hallward-Driemeier and Hasan (2012) provide a categorization of marital property rights regimes[8] in their study distinguishing among community property regime, separate property regime, and customary law regime. These categories are used to describe the default marital property systems in various countries[9]. In the community property regime, all property acquired during the course of a marriage is equally owned by both spouses. This contrasts with the separate property regime where individuals retain control over their respective properties including those acquired before and during the marriage. The community property regime is significant for women as it offers a more equitable distribution of property upon the dissolution of a marriage by death of a partner or divorce. This regime acknowledges the contribution of both spouses including the often non-monetized activities performed by women, particularly in SSA contexts. In contrast, the separate property regime requires individuals to establish proof of ownership to claim property rights which can be more challenging for women who may have contributed in non-financial ways to the marital assets. The customary law property regime presents a more complex picture. It varies significantly across regions sometimes involving communal ownership or in many cases reflecting male-dominated ownership structures.

These differences in property regimes are deeply rooted in historical and legal traditions. The impact of these legal traditions on economic performance has been extensively explored in research. As aforementioned, various studies have examined how legal traditions correlate with outcomes like bank ownership by governments, barriers to business entry, labor market regulations, state ownership in media, female HIV rates, and rates of deforestation. As pointed out by Marchand (2011), this Legal Origin theory[10] in Africa rests on three key concepts. First, it recognizes that continental Europe and Great Britain, known for civil law and common law respectively, developed unique systems for economic governance that significantly differ from each other. Second, these legal traditions were introduced to Africa through colonialism, making them exogenous. Lastly, these systems continue to play a crucial role in shaping social and economic policies. Broadly speaking, there are three legal systems present in Sub-Saharan Africa: civil law, common law, and customary law.

The community property regime is closely linked to civil law, which originated in continental Europe and was introduced to countries colonized by European nations such as France, Portugal, Spain, Italy, and Belgium. Conversely, the separate property regime is prevalent in

8 This law is particularly important for women, as marriage is nearly universal in Africa and it significantly influences household bargaining power (Anderson 2018).

9 The type of property regime largely determines a woman's ability to own property during marriage and on its dissolution through divorce or death.

10 This is an economic concept that examines how the historical origins of a country's legal system influence its economic outcome and overall development.

common law systems, which began in England and are based on feudal traditions, (Dainow 1966, Donahue 1979, Hallward-Driemeier and Hasan 2012, and Anderson 2018). A study closely related to this is that of Anderson (2018), who provides evidence that British common law in SSA is associated with weaker female martial property rights than civil law. The study shows that this weaker rights affects the ability of women to negotiate for a safer sex in common law countries leading to "feminization of HIV.[11]"

2.2 Female Bargaining Power and Deforestation

In this paper, deforestation is defined as the complete transition from a forested to a non-forested state. A forested state is characterized by a tree canopy closure including all vegetation that is taller than 5 meters (Hansen et al. 2013). African forest tenure is marked by its complexity stemming from a mix of different legal and cultural systems (Romano and Reeb, n.d.). This intricate array can be broadly classified into five categories: public (unmanaged), public (protected areas), private, communal, and customary traditional lands[12] (Robinson et al. 2014). I suggest that the dynamics in household bargaining power influences the use of both private and communal tenures where individual rights are either legally or locally recognized. Feminist theory suggests that women tend to be more environmentally conscious than men (Norgaard and York 2005), due to two key reasons: their greater vulnerability to the impacts of environmental degradation and the intrinsic link between sexism and environmental degradation.

Deforestation is impacting household livelihoods in numerous African countries. Typically, women are more susceptible to these deforestation-related issues compared to men (Steady 2014). For example, as forests are cleared, women who are often responsible for gathering household resources must travel further to collect essentials like fuelwood[13]. This is evident in Sudan, Nigeria and Tanzania, where women now spend significantly more time on fuelwood collection than they did in the past (Koda 2004, Aina 1998). Furthermore, research

11 See Anderson (2018) and Hallward-Driemer and Hasan (2012) for more detailed review on differences in these legal systems that affect their female bargaining power.

12 Public tenure includes unmanaged public frontiers or open access areas without specific management practices. Protected tenure refers to government-restricted public lands with defined conservation goals. Private tenure involves forests owned by individuals or entities with legal rights for land management. Communal tenure is characterized by community-wide use and management, with locally recognized individual rights. Customary tenure is rooted in traditional practices and norms.

13 Research has established that women are not major contributors to deforestation through firewood collection, as they primarily gather branches and dead wood. The major drivers of deforestation in Africa are land clearance for agriculture, commercial activities, and construction (refer to Steady 2014 for literature).

also indicates that environmental degradation and the climate crisis have more adverse effects on women compared to men, particularly in five key areas: agricultural production, food and nutrition security, health, water and energy resources, and issues related to climate-related disasters, migration, and conflict (Awiti 2022).
Other ecofeminist theories suggest a connection between sexism and environmental degradation, arguing that gender significantly influences the values, ideologies, institutions, and economic systems that govern human-environment interactions (Norgaard and York 2005, Merchant 1980). This theory points out that structural inequalities, which often give men more control over land resources, can lead to land degradation. This is because such inequalities limit women's participation and undervalue the knowledge they gain through extensive work on the land (Agarwal 2010, Doss et al. 2014, Johnson et al. 2016). Collectively, these theories presents two key points: first, women generally have more environmentally friendly preferences than men (Guarascio et al. 2013, Kiptot and Franzel 2012, and Steady 2014); and second, women's participation in local decision-making processes can reduce deforestation rates (Agarwal 2009, Filomina 2014, Leone 2019).

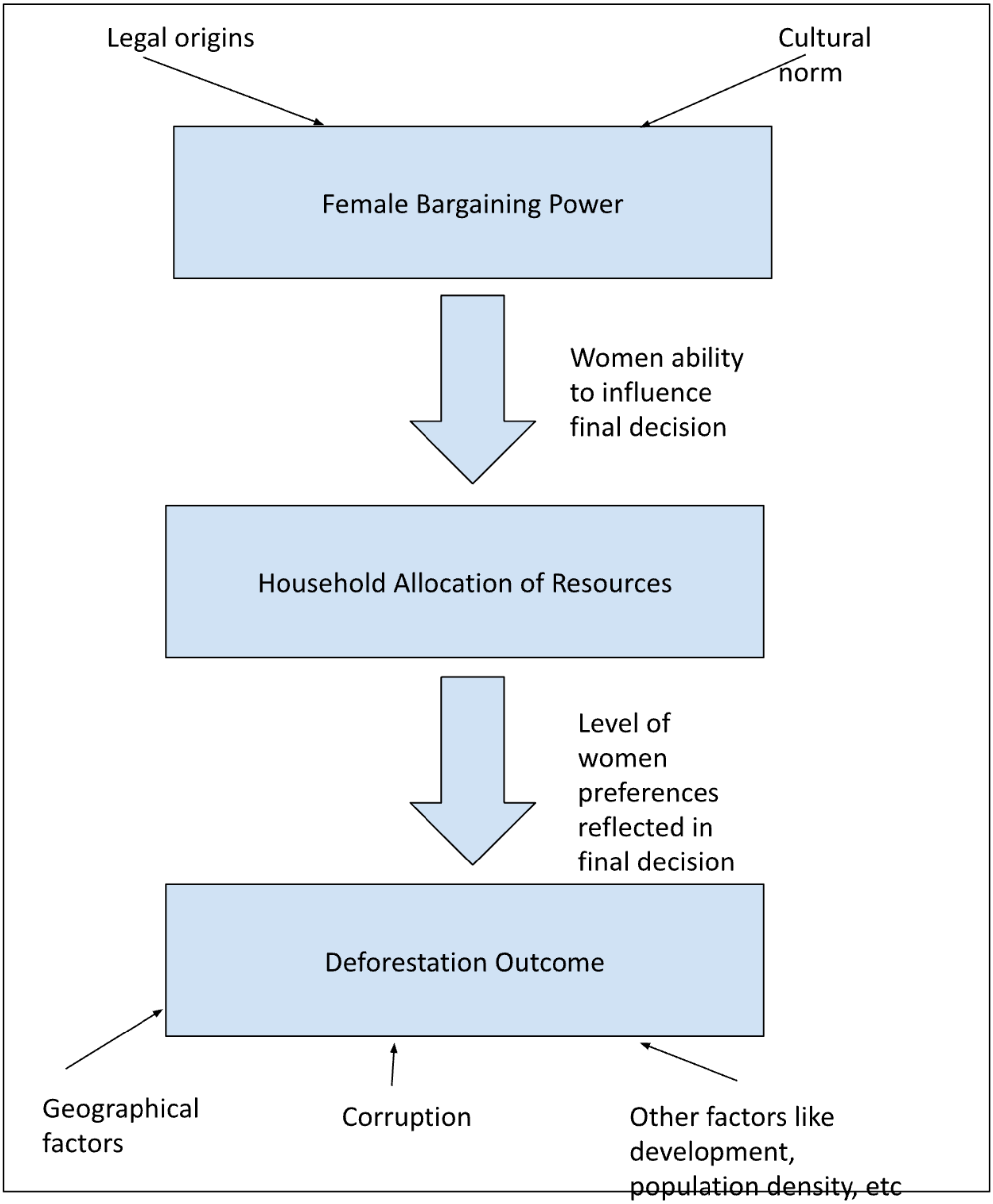
In households, women and their partners thus have distinct preferences regarding resource allocation, risk-taking, and responses to shocks and stressors, linked to their specific roles in livelihood maintenance (Ravera et al. 2016)[14]. Due to this varied interests within households, individuals need to negotiate to achieve their desired responses to deforestation-linked disturbances. Consequently, having agency is crucial, particularly for women, to ensure their needs and preferences are adequately represented in the responses to these stressors (Byran et al. 2023). Marital property rights contribute to creation of this agency by affecting women's exit option (Heath and Ciscel 1996)[15]. In common law countries, where women have less favorable options upon exiting a marriage, their relative bargaining power to achieve favorable outcomes is limited. As a result, the decisions made within the household are more likely to reflect the preferences of men rather than those of women.

Given this constraint, my hypothesis is that countries with civil law systems will exhibit lower rates of deforestation compared to those with common law systems. It is worth noting that various factors like corruption, education levels, rural density, and property rights can impact the results of this model. La Porta et al. (2008) note that civil law systems often have great-

14 Specifically, women tend to concentrate on the subsistence use of forests and gathering of non-timber forest products, whereas men are more involved in commercial forest activities such as logging, harvesting a limited range of high-value forest products for sale, and construction (Cavendish 2000, Shackleton et al. 2001).

15 The authors present a new bargaining framework, the Sisyphus Syndrome paradigm, which suggests that women without a wage income often stay in marriages due to limited feasible alternatives. Building upon this, I suggest that women under common law systems are more impacted by this scarcity of alternatives compared to those in civil law systems, as they lack guaranteed legal protections

er government control and regulation than common law systems which can lead to higher levels of corruption compared to countries with common law systems that tend to be less interventionist, more efficient in public service delivery, and more democratic. Education also plays a crucial role in climate change awareness. Simpson et al. (2021) highlight that climate change literacy improves with higher education levels which significantly influences attitudes towards climate change. Despite women generally being less aware of climate issues and more vulnerable to climate change impacts, in Africa, they are more likely to adopt climate-resilient crops when they are educated about climate change and have access to extension services (Simpson et al. 2021). This is particularly relevant given Baten et al. (2021)'s findings of an educational disparity between British and French colonies making literacy rates a potential confounding factor. Additionally, the density of rural populations and the enforcement of property rights are crucial national metrics. The impacts of climate change are often more acute in rural areas, where livelihoods are more directly dependent on climate-sensitive activities. Therefore, understanding the rural-urban divide is essential. Moreover, the level of property rights in a country is significant as it influences attitudes towards environmental issues like deforestation.



Notes: The diagram above provides a simplified visualization of the argument outlined previously. It shows how legal origins and cultural norms shape female bargaining power, which in turn affects women's ability to participate and influence decision-making. The decisions reached impact how household resources are allocated, reflecting women's preferences based on their bargaining power. Given the gender disparity in environmental outcomes, these decisions ultimately influence local deforestation rates.

3 Data

This paper utilizes two complementary types of data for conducting a spatial regression discontinuity analysis: country-level and pixel-level data. Pixel-level data is essential as it captures specific deforestation, ethnic and geographical details for each pixel – the unit of observation. Conversely, country-level data offers a broader perspective that is vital for controlling variables and ensuring the robustness of the analysis.

3.1 Pixel Level Data

The study area is methodically divided into grid cells (i.e., pixels), each measuring 12.5 by 12.5 km. Within these cells, I compiled data pertaining to ethnicity, geography, and deforestation rates. The core data for ethnicity and geography primarily comes from the work of Michalopoulos and Papaioannou (2013). Their research uses historical ethnic distributions from Murdock's 19th-century map with contemporary national boundaries, focusing on how ethnicities are divided among different modern states. They classified an ethnicity as 'partitioned' if at least 10% of its ancestral homeland is spread across more than one present-day nation. Their data reveal a total of 526 such partitions, encompassing 227 distinct ethnic groups. Of these, 155 distinct ethnic groups are situated in partitions around continental SSA, while the remainder are in North Africa and other SSA islands like Madagascar. Accounting for ethnic institutions is crucial, given that deforestation in Africa has been associated with pre colonial institutions (Larcom et al. 2015)[16]. Additionally, the dataset contains a wide range of geographical information for each pixel, including factors such as distance to capital, malaria suitability, elevation, distance from the sea, logarithm of population density, indicators for petroleum and diamond presence, and water availability. The inclusion of malaria suitability as a control is based on MacDonald's (2019) finding that higher malaria burdens significantly reduce deforestation rates[17]. Additionally lower elevations are more prone to deforestation due to their accessibility for activities like agriculture and logging (Harris et al. 2014). Rudel (2013) also notes that drier forests have higher deforestation rates, and the presence of oil and mineral industries often leads to rural-urban migration, a decline in agriculture, and increased cereal imports. Therefore, I also control for the presence of water, diamonds, and petroleum in each pixel[18]. Lastly, I incorporate controls for the distance from

16 See Appendix for graphical representation of their results.

17 Appendix Figures A2 and A3 display the distribution of malaria suitability across legal origins, and the relationship between deforestation and malaria suitability, respectively.

18 See figure A4, A5, and A6 for the correlation between these variables and deforestation rate.

the capital city, national borders, and the coast, as these factors are linked to the level of development (Michalopoulos and Papaioannou 2013), which in turn affects deforestation rates (Ortiz 2021). This extensive array of geographical variables offers robust controls, enhancing the reliability of my analyses.

The deforestation information for each pixel is sourced from the Global Forest Change dataset created by Hansen et al. (2013). Originally, this dataset presents data in a fine-grained 30 by 30 m sub-pixel format. To align with the larger 12.5 by 12.5 km grid cells used by Michalopoulos and Papaioannou (2013), I have transformed the deforestation data accordingly. As an example, Figure 3 illustrates the configuration of pixels and sub-pixels within Gabon (not drawn to scale). For assessing deforestation rates, the approach began by segmenting the country into pixels of 12.5 by 12.5 km dimensions (an example marked in red). This division produced 1,148 such pixels for Gabon. Each full pixel (not cutoff by the national border) includes approximately 173,611 smaller sub-pixels, each sized at 30 by 30 meters (an example indicated in green). Hansel et al. (2013) provided data for each sub-pixel indicating whether the sub-pixel underwent complete deforestation (represented by 1) or not (0). The deforestation rate at the pixel level was calculated by averaging the values of all sub-pixels within a pixel. Figures A14 and A15 in the appendix reveal a widespread occurrence of low deforestation rates among the pixels, though a greater proportion of pixels within civil law countries exhibit higher deforestation rates in comparison to their common law counterparts. The pixel center's latitude and longitude is used in identifying each pixel. For instance, the pixel located at latitude and longitude coordinates of .9429961, 9.766887 exhibited a deforestation rate of 0.32%. This rate was derived from approximately 563 completely deforested sub-pixels out of the 173,611 present in that pixel. A similar methodology was applied to calculate deforestation rates across all other pixels in SSA. Figure A7 in the Appendix shows the deforestation rates across SSA countries.

3.2 Country Level Data

This study necessitates data on the legal systems of various countries, for which La Porta et al. (2008) served as the primary source. Their dataset offers legal origins for nearly all countries in SSA[19]. Figure 4 displays the countries categorized under each legal system (common law

19 Seven countries were not included in the dataset. These include: Angola, Democratic Republic of Congo (DR Congo), Burundi, Eritrea, South Sudan, Somalia, and Sudan. Joireman (2004) identifies Angola and DR Congo as civil law countries. Similarly, Burundi and Eritrea are categorized as civil law nations according to the Media Law Handbook for Eastern Africa and the Library of Congress, respectively. On the other hand, Sudan and South Sudan are classified as common law countries, as stated by the United Nations (UN, 2020). Although Somalia's legal system has nuances, particularly with the applicability of Sharia law as discussed by Maru (2008), it is categorized as a common law country for this study due to its similar female

and civil law). Out of the 43 countries included in my study, 25 belong to common law systems and 18 to civil law systems. However, we excluded Namibia, South Africa, and Lesotho from the final analysis. Although these countries are primarily under common law, they have a hybrid marital property rights system influenced by Dutch Roman law (Hallward-Driemeter and Hasan 2012, Anderson 2018). In my analysis, 44.8% of the pixels are under jurisdictions with a common law regime. To supplement this data, I used the World Bank Indicator dataset to gather country-specific information. This includes the CPIA rating which evaluates how effectively a legal system facilitates private economic activity by reliably respecting and enforcing property and contract rights. Additionally, the database provided data on adult literacy rates, the percentage of the rural population, and the percentage of women employed in agriculture. Although this information is not available at the pixel level, it is vital for offering controls in comparing different legal systems.

For regional fixed effects, I incorporated the United Nations' classification of subregions in Africa into the dataset[20]. As an extra control measure, data from The Guardian was used to determine the Muslim population in these countries. This is crucial for the analysis as the dynamics of female bargaining power differ in Muslim-majority countries and the study aims to account for these variations. Anderson (2018) argues that the stronger marital property rights in civil law countries do not apply to Muslims for whom the default regime is separate marital property rights.

3.3 Data Patterns

Tables 1 and 2 offer detailed summary statistics of the data encompassing 110,113 pixel-level observations. A critical observation from Table 2 is the notable disparity in deforestation rates between common law and civil law countries. Figure A9 in the appendix shows a visual representation of this disparity. Unexpectedly, civil law countries exhibit substantially higher deforestation rates than their common law counterparts. Furthermore, the data also indicates that common law countries boast significantly higher adult literacy rates. This factor could show better environmental awareness leading to a stronger public advocacy for conservation efforts. Alongside this, common law nations show marginally higher levels of agricultural suitability and elevation as well as a slightly stronger rule of law. Conversely, civil law countries are characterized by marginally stronger property rights enforcement, higher malaria suitability, increased levels of corruption, and a greater percentage of the population

bargaining power to other common law nations.

20 Figure A8 shows the differences in deforestation rate in different regions in SSA. There is a clear disparity among the regions

residing in rural areas. These factors in civil law countries could be facilitating or exacerbating the deforestation issue. For instance, stronger property rights combined with higher corruption levels might lead to easier access to forest lands for exploitation. Similarly, the rural population's dependency on agriculture and land use might be driving deforestation activities. Given these varied results, it becomes challenging to isolate specific variables that predominantly influence the significant differences in deforestation rates between the two legal systems. Lastly, the dataset reveals that approximately 27% of the countries included have a majority Muslim population.

4 Empirical Strategy

In my study, I utilize a spatial regression discontinuity design to determine the average impacts of female bargaining power on the rate of deforestation. The main empirical model is represented as follows:

$$y_{p,i,c} = \alpha_0 + \beta L_c + f(BD) + f(BD * L_c) + \phi X'_{p,i,x} + \Delta X'' + +\varepsilon + \delta + \epsilon$$

The dependent variable, $y_{p,i,c}$, denotes the deforestation rate within a pixel p, categorized by ethnicity i, in country c. Rather than using the absolute deforestation rate, I calculate its logarithmic transformation[21] by adding a small constant (0.01) to accommodate zero values $y_{p,i,c} = ln(0.01 + deforestation_{p,i,c})$[22]. This approach is advantageous as it manages extreme values[23] in the dataset and allows for the inclusion of all observations since a substantial portion of the data records zero deforestation[24].

The independent variable, L_c, represents the legal system of the country c where the pixel is located. This variable is a dummy indicator set to 1 for common law systems and 0 for civil law systems. The model includes a function of the distance to the nearest border, $f(BD)$, and its interaction with the common law indicator, $f(BD) * L_c$. The term X' denotes pixel-level control variables, which cover a range of factors: malaria suitability, elevation, agri-

21 I also conducted the main estimation using the absolute deforestation rate. The outcomes of this estimation are detailed in the Appendix section of this paper.

22 Refer to Michalopoulos and Papaioannou (2013) for a format similar to the one discussed.

23 See the distribution of deforestation values as presented in Figure A14 and A7 for pixel and country level, respectively.

24 Given that our measurement of the deforestation rate is based on the total removal of tree canopy in a 30 x 30 m subpixel, it is understandable that some areas would show 'no deforestation.' However, it is crucial to acknowledge that this approach might overlook instances of partial deforestation within these areas. Consequently, this method may lead to an underestimation of the impact of female bargaining power on the overall deforestation rate.

cultural suitability, proximity to the sea and the capital city, the logarithm of population size, and the presence of diamond and petroleum mines, as well as water bodies. Country-level controls are represented by X'', including variables such as the adult literacy rate, property rights index, and rural population density. Additionally, $\mathcal{E}$ and Δ are fixed effects for ethnicity and region, respectively. The error term, denoted as ϵ, is clustered at both the country and ethnicity levels to account for potential correlation within these groups. In alternative specifications, I restrict the analysis to areas within 100 km and 50 km of the border to specifically examine the effects in regions close to the border. Additionally, I exclude countries with a Muslim-majority population (see Figure A12 in the appendix) from the analysis as these communities commonly practice polygamy which may influence the outcomes being studied (Anderson 2018).

5 Results

5.1 Preliminary Investigation

Prior to delving into the results, it's important to share some insights observed from the data. A detailed examination of how female bargaining power impacts deforestation reveals a range of mixed outcomes. For example, the Nyasa ethnic group is divided between Mozambique, Tanzania, and Malawi. The partitioning of the Nyasa shows that approximately 62% of their territory falls within Mozambique while Tanzania and Malawi account for the other 28% and 10% respectively. The analysis reveals a clear disparity in deforestation rates contrary to my proposed hypothesis: while Malawi and Tanzania, both under common law systems exhibit similar rates of 4.19% and 4.95%, Mozambique (civil law) has a significantly higher rate of 8.75%. This variation is different from the national deforestation rates, which are 4.41% for Malawi, 6.39% for Tanzania, and 7.92% for Mozambique.

However an exploration of other ethnic groups presents a puzzling trend. For instance, the Nkole—an ethnic group spread across Uganda, Tanzania, and Rwanda—exhibits an opposite pattern. In this case, the deforestation rate, as expected, is higher in common law countries compared to a civil law country. Specifically, Uganda shows a deforestation rate of 5.13%, which is higher than Tanzania's 1.20% and Rwanda's 0.6%, despite their respective national averages being 5.74%, 6.36%, and 3.01%. Uganda and Tanzania, both common law countries, have similar national average deforestation rates, yet the areas inhabited by the Nkole in these countries demonstrate different deforestation rates. On the other hand, Rwanda, a civil law country, exhibits a lower deforestation rate in the Nkole-inhabited areas. This variability suggests a more interesting relationship between legal regimes and deforestation rates that I seek to uncover. Lastly, the Chewa ethnic group, divided among Mozambique (45%), Malawi (35%), and Zambia (20%), demonstrates varying deforestation rates: 5.58%

in Mozambique, 2.97% in Malawi, and 6.70% in Zambia. Notably, both Malawi and Zambia operate under common law systems. However, the deforestation rate in the Zambian portion is higher than in Mozambique, which follows a civil law system, while Malawi's rate is lower than Mozambique's. Nonetheless, a visual analysis (see Figure A10) by legal origins indicates that for the Nyasa and Chewa tribes, aggregate deforestation rates are generally higher in civil law countries compared to common law countries. Conversely, the Nkole tribe exhibits the opposite trend, with lower deforestation rates in civil law countries. Further analysis of other ethnic groups such as Hlengwe and Nsenga show a trend similar to that of the Nyasa and Chewa, indicating that deforestation rates are generally higher in civil law countries as opposed to common law countries.

5.2 Graphical Representation

Lee and Lemieux (2009) argue that if the graph does not show any clear discontinuity, it is unlikely that regression discontinuity (RD) analysis will produce a significant effect. Based on this, I visually represented my findings by displaying the average deforestation rate in 5 km bins. I use two bandwidths, 100 km and 50 km, respectively, for this visualization. Figure 5 reveals no statistically significant differences in (absolute) deforestation as illustrated by the intersection of standard error lines. On the civil law side (negative distance values), the deforestation rate appears relatively constant or slightly decreasing as one moves away from the border. However, on the common law side (positive distance values), there's an initial decrease in deforestation rates just after the border, which then gradually levels off or increases as the distance from the border increases. Figure A11 in the appendix demonstrates that these patterns persist even when the distance is narrowed to 50 km. Additionally, Figure A16 depicts the log-transformed deforestation data, employing similar methodologies to those outlined above, and reveals consistent trends between civil law and common law similar to Figures 5 and A11.

5.3 Baseline Results

Table 3 presents regression discontinuity (RD) analysis to investigate the impact of female bargaining power on the rate of deforestation. For columns (1), (2), and (3), the analysis includes all available pixels across the geographical divide marked by national borders within ethnically homogenous regions. The study accounts for the non-linear effects of proximity to national borders by integrating linear, quadratic, and cubic distance variables into the regression models. These models indicate that common law countries experience lower rates of deforestation than civil law countries, a finding reinforced by the results being statistically significant at 5% level. Specifically, column (1) reveals that common law countries see a reduction in the deforestation rate by 38.06%, while columns (2) and (3) report reductions of 38.61% and 35.27%, respectively[25]. These figures underscore the consistently lower deforestation rates associated with common law systems. Additionally, the R-squared values are high, at approximately 77.6%, suggesting that the models explain a significant portion of the variation in deforestation rates after log transformation.

The analysis then narrows the scope in specifications (4) and (5), focusing on pixels within 100 km and 50 km of national borders, using a squared distance function for greater precision. These specifications yield a 32.9% and 27.67% lower deforestation rate in common law countries, respectively. Notably, these results are statistically significant at the 10% level, indicating a less robust yet still notable relationship between female bargaining power and deforestation within these more limited distances. A particularly compelling finding emerges when the dataset excludes countries with a Muslim majority. Under this condition, common law countries demonstrate a 53.55% lower deforestation rate compared to civil law countries. This effect is highly statistically significant, with a p-value less than 0.01, suggesting a strong negative association between common law and deforestation rates when Muslim majority countries are not considered. Paradoxically, these results imply that increased female bargaining power is associated with an increase in deforestation rates. This counterintuitive outcome may suggest that as women gain more institutional bargaining power, their influence on household decision-making actually decreases. This could be because men, perceiving a loss in their traditional roles, may attempt to assert more control over household decisions to compensate for their perceived loss in masculinity.

5.4 Robustness Check

Table 2A displays the relationship between female bargaining power and the absolute rates of deforestation, employing specifications identical to those used for the log-transformed deforestation rates. Across all models, the data indicate that countries with common law systems have lower deforestation rates than those with civil law systems. However, the degree of this relationship varies slightly depending on the model specification. In the initial three models (1) to (3) which account for the linear, quadratic, and cubic terms of the distance to national borders, the coefficients are -1.010, -1.126, and -1.033, respectively[26]. Further specifications, model (4) which considers areas within 100 km of a border, and model (5) which narrows

25 This percentage change is determined by the formula $(e^\beta - 1) \times 100\%$, where β is the estimated coefficient from the regression model.

26 Considering that the average deforestation rate across all pixels stands at 4.76, these results show significant differences in the impact of female bargaining power on deforestation rates.

it down to within 50 km yield coefficients of -0.867 and -0.633, respectively. In the most focused analysis, model (6) excludes countries with a Muslim majority and reports a coefficient of -2.488[27]. Despite these negative coefficients, which suggest a lower rate of deforestation in common law countries, only the result from model (6) is statistically distinguishable from zero. This observation is in alignment with the findings from the log-transformed deforestation data, reinforcing the notion that the lower female bargaining power is linked to more favorable environmental outcomes in terms of forest conservation. Thus, while the absolute deforestation rates reflect a similar trend to the log-transformed rates, the strength and clarity of the relationship are most apparent when examining common law countries without a Muslim majority.

These findings align with the visual illustration presented in Figure 5, Figure A9, and Figure A10, which indicate that civil law countries exhibit higher deforestation rates than common law countries. The lack of statistical significance for these results is consistent with the earlier graphical representations from regression discontinuity (RD) analyses (Figure 5). These graphs illustrate overlapping standard errors, implying that the confidence intervals include zero thereby precluding the ability to assert a statistically significant difference from zero in the estimate.

6 Conclusion

The analysis reveals that common law countries tend to have lower deforestation rates compared to civil law countries. Intriguingly, it also suggests that as women gain more bargaining power institutionally, deforestation rates may increase. The most compelling explanation for this unexpected outcome lies in the concept of "doing gender" from gender studies (West and Zimmerman 1987). This theory argues that gender behaviors are performative acts carried out in everyday interactions, aligning to societal expectations of what is considered masculine and feminine. These acts serve to affirm individuals' belonging to their socially recognized gender categories and uphold societal division. This framework helps explain why women who out-earn their partners may face increased domestic violence and emotional abuse (Zhang and Robert 2023). In this dynamic, women may exhibit submissiveness to align with traditional gender roles while men may assert control in other areas to reestablish their challenged masculinity (Mabsout and Staveren 2010). These gendered compensatory behaviors suggest that while civil law regimes may grant women more autonomy and negotiating leverage, such benefits may not necessarily translate into influence over household

27 Table 3A and Table 4A, which is not discussed here, demonstrates that these trends remain consistent across all other specifications. For a graphical representation of these results on non-Muslim majority countries, refer to Figure A13.

decisions making, like resource allocation.

Nonetheless, future research should explore the impact of female bargaining power on deforestation rates more thoroughly by considering the following factors. First, it is important to focus on deforestation in areas where individual rights are locally or legally recognized. This approach is crucial because analyzing deforestation at the pixel level across all lands can introduce bias. Such broad analysis fails to account for the distinct contributions of public protected lands, customary traditional lands, and unmanaged public lands, where individual rights are not recognized. These nuances were not considered in my study. Moreover, the legal framework of a country can influence deforestation outcomes in these lands. For instance, common law countries are often less interventionist and might be more efficient in managing public goods. This efficiency is typically due to reduced bureaucratic delays and lower corruption levels (Lopez-de-Silanes 1999). These differences introduce a significant bias from the management of public protected lands, for instance, that was not considered in my study[28].

Second, and more importantly, common law's flexibility and its approach to nonprofits may enhance its effectiveness in environmental protection. Common law systems due their reliance on precedents, can adapt more swiftly to the evolving needs of forest conservation unlike the more rigid, codified structure of civil law systems. Anderlini et al. (2020) show that this adaptability results in superior welfare outcomes under common law compared to civil law across various parameters. Furthermore, in civil law countries, the state predominantly oversees serving the common good within the realm of public law. Here, the rights of nonprofits to act in the public interest are granted by public institutions through specific legal provisions. Conversely, in common law systems, private institutions independently assert their right to serve the public interest. Salamon and Helmut (1992) observe that in civil law countries, the firm regulation and close alignment of nonprofits with the state may limit their activities. This contrasts with the greater flexibility available under common law. As a result, in civil law countries, the nonprofit sector might face more challenges in advocating for environmental protection. The lesser autonomy for environmental advocacy under civil law could potentially lead to weaker environmental enforcement, compared to the more independent and dynamic role that nonprofits can play in common law countries. My study fails to account for both of this due to time constraints in finding data.

28 The protection of biodiversity and the reduction of deforestation are closely linked to the establishment of protected areas (Abman in 2018) while FAO argues that a large proportion of land is under government management.

References

[1] Abman, Ryan. "Rule of Law and Avoided Deforestation from Protected Areas." Ecological Economics 146 (April 1, 2018): 282–89. https://doi.org/10.1016/j.ecolecon.2017.11.004.

[2] Abman, Ryan, Teevrat Garg, Yao Pan, and Saurabh Singhal. "Agriculture and Deforestation." SSRN Scholarly Paper. Rochester, NY, September 14, 2020. https://doi.org/10.2139/ssrn.3692682.

[3] Abugre, Simon, and Emmanuel Kwaku Sackey. "Diagnosis of Perception of Drivers of Deforestation Using the Partial Least Squares Path Modeling Approach." Trees, Forests and People 8 (June 1, 2022): 100246. https://doi.org/10.1016/j.tfp.2022.100246.

[4] Agarwal, Bina. "Gender and Forest Conservation: The Impact of Women's Participation in Community Forest Governance." Ecological Economics 68, no. 11 (2009): 2785–99. https://doi.org/10.1016/j.ecolecon.2009.04.025.

[5] Aina, Olabisi., and Adetanwa. Odebiyi. "Domestic Energy Crisis in Nigeria: Impact on Women and Family Welfare." African Economic History, no. 26 (1998): 1–14. https://doi.org/10.2307/3601688.

[6] Akinola, Adeoye. "Women, Culture and Africa's Land Reform Agenda." Frontiers in Psychology 9 (2018). https://www.frontiersin.org/articles/10.3389/fpsyg.2018.02234.

[7] Amanor-Wilks, Dede-Esi. "Land, Labour and Gendered Livelihoods." Feminist Africa 12, December 2009, 31–50.

[8] Anderlini, Luca, Leonardo Felli, and Alessandro Riboni. "Legal Efficiency and Consistency." European Economic Review 121 (January 1, 2020): 103323. https://doi.org/10.1016/j.euroecorev.2019.103323.

[9] Anderson, Siwan. "Legal Origins and Female HIV." The American Economic Review 18, no. 6 (2018): 1407–39. https://www.jstor.org/stable/26528013.

[10] Awiti, Alex. "Climate Change and Gender in Africa: A Review of Impact and Gender-Responsive Solutions." Frontiers in Climate 4 (2022). https://www.frontiersin.org/articles/10.3389/fclim.2022.895950.

[11] Baten, Joerg, Michiel de Haas, Elisabeth Kempter, and Felix Meier zu Selhausen. "Educational Gender Inequality in Sub-Saharan Africa: A Long-Term Perspective." Population and Development Review 47, no. 3 (2021): 813–49. https://doi.org/10.1111/padr.12430.

[12] Brack, Duncan. "Forests and Climate Change." United Nations Forum on Forests Forest and SDG13 (2019). https://www.un.org/esa/forests/wp-content/uploads/2019/03/UNFF14-BkgdStudy-SDG13-March2019.pdf.

[13] Bryan, Elizabeth, Claudia Ringler, and Ruth Meinzen-Dick. "Gender, Resilience, and Food Systems." In Resilience and Food Security in a Food Systems Context, edited by Christophe Béné and Stephen Devereux, 239–80. Palgrave Studies in Agricultural Economics and Food Policy. Cham: Springer International Publishing, 2023. https://doi.org/10.1007/978-3-031-23535-1_8.

[14] Caliskan, Erhan. "Environmental Impacts of Forest Road Construction on Mountainous Terrain." Iranian Journal of Environmental Health Science & Engineering 10, no. 1 (March 15, 2013): 23. https://doi.org/10.1186/1735-2746-10-23.

[15] Cavendish, William. "Empirical Regularities in the Poverty-Environment Relationship of Rural Households: Evidence from Zimbabwe." World Development 28, no. 11 (November 1, 2000): 1979–2003. https://doi.org/10.1016/S0305-750X(00)00066-8.

[16] Chen, Keren, Qiyuan Cai, Nan Zheng, Yinan Li, Changyong Lin, and Yuanfei Li. "Forest Carbon Sink Evaluation – An Important Contribution for Carbon Neutrality." IOP Conference Series: Earth and Environmental Science 811, no. 1 (July 1, 2021): 012009. https://doi.org/10.1088/1755-1315/811/1/012009.

[17] Dainow, Joseph. "The Civil Law and the Common Law: Some Points of Comparison." The American Journal of Comparative Law 15, no. 3 (1966): 419–35. https://doi.org/10.2307/838275.

[18] Demiralay, Sercan, Hatice Gaye Gencer, and Selcuk Bayraci. "Carbon Credit Futures as an Emerging Asset: Hedging, Diversification and Downside Risks." Energy Economics 113 (September 1, 2022): 106196. https://doi.org/10.1016/j.eneco.2022.106196.

[19] Donahue, Charles. "What Causes Fundamental Legal Ideas? Marital Property in England and France in the Thirteenth Century." Michigan Law Review 78, no. 1 (1979): 59–88. https://doi.org/10.2307/1288209.

[20] Ehrhardt-Martinez, Karen, Edward M. Crenshaw, and J. Craig Jenkins. "Deforestation and the Environmental Kuznets Curve: A Cross-National Investigation of Intervening Mechanisms." Social Science Quarterly 83, no. 1 (2002): 226–43.

[21] FAO, ed. Gender and Access to Land. FAO Land Tenure Studies 4. Rome: Food and Agricultural Organization, 2002.

[22] FAO. "Gender | REDD+ Reducing Emissions from Deforestation and Forest Degradation | Food and Agriculture Organization of the United Nations." Accessed January 13, 2024. https://www.fao.org/redd/areas-of-work/gender/en/.

[23] FAO, Sweden Sverige, and ECOWAS. "Gender Equality and Forestry in West Africa," CB4280EN/1/04.21, 2021. https://www.fao.org/3/cb4280en/cb4280en.pdf.

[24] Gachuiri, Agnes, Ana Maria Paez-Valencia, Marlène Elias, Sammy Carsan, and Stepha McMullin. "Gender and Generational Differences in Local Knowledge and Preference for Food Trees in Central Uganda and Eastern Kenya." Frontiers in Sustainable Food Systems 5 (2022). https://www.frontiersin.org/articles/10.3389/fsufs.2021.746256.

[25] Greenpeace Africa. "How Widespread Deforestation In Africa Risks Our Climate Future." Accessed January 12, 2024. https://www.greenpeace.org/africa/en/blogs/49073/how-widespread-deforestation-in-africa-risks-our-climate-future/.

[26] Global Forest Resources Assessment 2020. FAO, 2020. https://doi.org/10.4060/ca8753en.

[27] Godoy, Ricardo, and Manuel Contreras. "A Comparative Study of Education and Tropical Deforestation among Lowland Bolivian Amerindians: Forest Values, Environmental Externality, and School Subsidies." Economic Development and Cultural Change 49, no. 3 (April 2001): 555–74. https://doi.org/10.1086/452515.

[28] Guarascio, F., N. Gunewardena, C. Holding-Anyonge, B. Sijapati Basnett, Mwangi, B. Powell, S. Shackleton, A. Degrande, and C. Colfer. Forest, Food Security and Gender: Linkages, Disparities and Priorities for Action. FAO, 2013. https://www.cifor.org/knowledge/publication/4912/.

[29] Hallward-Driemeier, Mary, and Tazeen Hasan. 2012. "Empowering Women: Legal

Rights and Economic Opportunities in Africa." Africa Development Forum series. Washington, DC: Agence Française de Développement and the World Bank. 2012.

[30] Harris, J. Berton C., Dadang Dwi Putra, Stephen D. Gregory, Barry W. Brook, Dewi M. Prawiradilaga, Navjot S. Sodhi, Dan Wei, and Damien A. Fordham. "Rapid Deforestation Threatens Mid-Elevational Endemic Birds but Climate Change Is Most Important at Higher
[31] Elevations." Diversity and Distributions 20, no. 7/8 (2014): 773–85.

[32] Heath, Julia A., and David H. Ciscel. "Escaping the Fate of Sisyphus: Bargaining, Divorce, and Employment in the Patriarchal Family." Review of Radical Political Economics 28, no. 1 (March 1, 1996): 1–19. https://doi.org/10.1177/048661349602800101.

[33] Howard-Borjas, Patricia. "Women in the Plant World: The Significance of Women and Gender Bias for Botany and for Biodiversity Conservation." Wageningen Universiteit, 2001. Igini, Martina. "Deforestation in Africa: Causes, Effects, and Solutions." Earth.Org, March 24, 2022. https://earth.org/deforestation-in-africa/.

[34] Jimoh, S. O., and E. A. Haruna. "Contributions of Non-Timber Forest Products to Household Food Security and Income around Onigambari Forest Reserve, Oyo State, Nigeria." Journal of Environmental Extension 6 (September 10, 2007): 28–33. https://doi.org/10.4314/jext.v6i1.2758.

[35] Kanninen, Markku, Daniel Murdiyarso, Frances Seymour, Arild Angelsen, Sven Wunder, and Laura German. "The Direct and Underlying Causes of Deforestation and Degradation." Do Trees Grow on Money? Center for International Forestry Research, 2007. https://www.jstor.org/stable/resrep02091.8.

[36] Kimaro, J., and L. Lulandala. "Contribution of Non-timber Forest Products to Poverty Alleviation and Forest Conservation in Rufiji District Tanzania," 2017. http://www.suaire.sua.ac.tz/handle/123456789/4717.

[37] Kiptot, Evelyne, and Steven Franzel. "Gender and Agroforestry in Africa: A Review of Women's Participation." Agroforestry Systems 84, no. 1 (January 1, 2012): 35–58. https://doi.org/10.1007/s10457-011-9419-y.

[38] Koda, Bertha. "Women, Deforestation and Wood Fuel Crisis: The Case of Tanzania, Tanzania Journal of Development Studies, Vol. 5, No.2, 2004:53-72," September 2004. https://www.taccire.sua.ac.tz/handle/123456789/395.

[39] Larcom, S., T. van Gevelt, and A. Zabala. "Precolonial Institutions and Deforestation in Africa." Land Use Policy 51 (February 1, 2016): 150–61. https://doi.org/10.1016/j.landusepol.2015.10.030.

[40] Leone, M. "Women as Decision Makers in Community Forest Management: Evidence from Nepal." Journal of Development Economics 138 (2019): 180–91. https://doi.org/10.1016/j.jdeveco.2019.01.002.

[41] Lopez-de-Silanes, Florencio, Andrei Shleifer, and Robert Vishny. "The Quality of Government." Oxford University Press, 1999. https://scholar.harvard.edu/files/shleifer/files/qualilty_govt_jleo.pdf

[42] Mabsout, Ramzi, and Irene van Staveren. "Disentangling Bargaining Power from Individual and Household Level to Institutions: Evidence on Women's Position in Ethiopia." World Development 38, no. 5 (May 1, 2010): 783–96. https://doi.org/10.1016/j.worlddev.2009.11.011.

[43] MacDonald, Andrew J., and Erin A. Mordecai. "Amazon Deforestation Drives Malaria Transmission, and Malaria Burden Reduces Forest Clearing." Proceedings of the National Academy of Sciences of the United States of America 116, no. 44 (2019): 22212–18.

[44] MARCHAND, SÉBASTIEN. "The Colonial Origins of Deforestation: An Institutional Analysis." Environment and Development Economics 21, no. 3 (2016): 318–49. https://www.jstor.org/stable/26392634.

[45] Merchant, Carolyn. "The Death of Nature: Women, Ecology, and the Scientific Revolution." New York: Harper and Row, 1980.

[46] Michalopoulos, Stelios, and Elias Papaioannou. "NATIONAL INSTITUTIONS AND SUBNATIONAL DEVELOPMENT IN AFRICA." The Quarterly Journal of Economics 129, no. 1 (2013): 151–213. https://doi.org/10.1093/qje/qjt029.

[47] Ndugwa, Robert, Everlyne Nairesiae, and Oumar Sylla. "INTERACTIVE EXPERT PANEL The Role of Rural Women's Land Rights and Land Tenure Security in Reaching the SDGs," 2018.

[48] Norgaard, Kari, and Richard York. "Gender Equality and State Environmentalism."

Gender and Society 19, no. 4 (2005): 506–22. http://www.jstor.org/stable/30044614.

[49] Le Monde.fr. "Africa Makes Perilous Gamble on Carbon Markets." September 25, 2023. https://www.lemonde.fr/en/le-monde-africa/article/2023/09/25/africa-makes-perilous-gamble-on-carbon-markets_6139682_124.html.

[50] Okeke, Phil E. "Reconfiguring Tradition: Women's Rights and Social Status in Contemporary Nigeria." Africa Today 47, no. 1 (2000): 49–63. https://www.jstor.org/stable/4187307

[51] Ortiz, Diana I., Marta Piche-Ovares, Luis M. Romero-Vega, Joseph Wagman, and Adriana Troyo. "The Impact of Deforestation, Urbanization, and Changing Land Use Patterns on the Ecology of Mosquito and Tick-Borne Diseases in Central America." Insects 13, no. 1 (December 23, 2021): 20. https://doi.org/10.3390/insects13010020.

[52] Pan, Yude, Richard A. Birdsey, Jingyun Fang, Richard Houghton, Pekka E. Kauppi, Werner A. Kurz, Oliver L. Phillips, et al. "A Large and Persistent Carbon Sink in the World's Forests." Science 333, no. 6045 (August 19, 2011): 988–93. https://doi.org/10.1126/science.1201609.

[53] Porta, Rafael La, Florencio Lopez-de-Silanes, and Andrei Shleifer. "The Economic Consequences of Legal Origins." Journal of Economic Literature 46, no. 2 (May 1, 2008): 285–332. https://doi.org/10.1257/jel.46.2.285.

[54] Ravera, Federica, Berta Martín-López, Unai Pascual, and Adam Drucker. "The Diversity of Gendered Adaptation Strategies to Climate Change of Indian Farmers: A Feminist Intersectional Approach." Ambio 45, no. 3 (December 1, 2016): 335–51. https://doi.org/10.1007/s13280-016-0833-2.

[55] Robinson, Brian E., Margaret B. Holland, and Lisa Naughton-Treves. "Does Secure Land Tenure Save Forests? A Meta-Analysis of the Relationship between Land Tenure and Tropical Deforestation." Global Environmental Change 29 (November 1, 2014): 281–93. https://doi.org/10.1016/j.gloenvcha.2013.05.012.

[56] Romano, Francesca, and Dominique Reeb. "UNDERSTANDING FOREST TENURE IN AFRICA: OPPORTUNITIES AND CHALLENGES FOR FOREST TENURE DIVERSIFICATION," n.d.

[57] Rudel, Thomas K. "The National Determinants of Deforestation in Sub-Saharan Af-

rica." Philosophical Transactions of the Royal Society B: Biological Sciences 368, no. 1625 (September 5, 2013): 20120405. https://doi.org/10.1098/rstb.2012.0405.

[58] Salamon, Lester M., and Helmut K. Anheier. "In Search of the Non-Profit Sector. I: The Question of Definitions." Voluntas: International Journal of Voluntary and Nonprofit Organizations 3, no. 2 (1992): 125–51.

[59] Sanjou, M., T. Okamoto, and I. Nezu. "Experimental Study on Fluid Energy Reduction through a Flood Protection Forest." Journal of Flood Risk Management 11, no. 4 (2018): e12339. https://doi.org/10.1111/jfr3.12339.

[60] Shackleton, C.M., S.E. Shackleton, and B. Cousins. "The Role of Land-Based Strategies in Rural Livelihoods: The Contribution of Arable Production, Animal Husbandry and Natural Resource Harvesting in Communal Areas in South Africa." Development Southern Africa 18, no. 5 (2001): 581–604. https://doi.org/10.1080/03768350120097441.

[61] Shackleton, S., F. Paumgarten, H. Kassa, M. Husselman, and M. Zida. "Opportunities for Enhancing Poor Women's Socioeconomic Empowerment in the Value Chains of Three African Non-Timber Forest Products (NTFPs)." International Forestry Review 13, no. 2 (2011): 136–51. https://doi.org/10.1505/146554811797406642.

[62] Shandra, John M., Bruce London, and John B. Williamson. "Environmental Degradation, Environmental Sustainability, and Overurbanization in the Developing World: A Quantitative, Cross-National Analysis." Sociological Perspectives 46, no. 3 (2003): 309–29. https://doi.org/10.1525/sop.2003.46.3.309.

[63] Shandra, John M., Carrie L. Shandra, and Bruce London. "Women, Non-Governmental Organizations, and Deforestation: A Cross-National Study." Population and Environment 30, no. 1/2 (2008): 48–72. http://www.jstor.org/stable/40279515.

[64] Sheil, Douglas, and Daniel Murdiyarso. "How Forests Attract Rain: An Examination of a New Hypothesis." BioScience 59, no. 4 (April 2009): 341–47. https://doi.org/10.1525/bio.2009.59.4.12.

[65] Sieböck, Gregor. "A Political , Legal and Economic Framework for Sustainable Forest Management in Cameroon . Concerted Initiatives to Save the Rainforests," 2002. https://www.semanticscholar.org/paper/A-Political-%2C-Legal-and-Economic-Framework-for-in-.-Sieb%C3%B6ck/22992c03bbe0d7fb18e13a60a074b83422a0ee91.

[66] Simpson Nicholas P., Talbot M. Andrews, Matthias Krönke, Christopher Lennard, Romaric C. Odoulami, Birgitt Ouweneel, Anna Steynor, and Christopher H. Trisos, 2021. "Climate change literacy in Africa," Nature Climate Change, Nature, vol. 11(11), pages 937-944, November.

[67] Steady, Filomina Chioma. "Women, Climate Change and Liberation in Africa." Race, Gender & Class 21, no. 1/2 (2014): 312–33.

[68] The Economist. "Could Carbon Credits Be Africa's next Big Export?" Accessed January 12, 2024. https://www.economist.com/middle-east-and-africa/2023/11/30/could-carbon-credits-be-africas-next-big-export.

[69] UN WomenWatch. "Women, Gender Equality and Climate Change." Accessed January 13, 2024. https://www.un.org/womenwatch/feature/climate_change/.

[70] "UNSD — Methodology." Accessed January 29, 2024. https://unstats.un.org/unsd/methodology/m49/#geo-regions.

[71] WEST, CANDACE, and DON H. ZIMMERMAN. "Doing Gender." Gender & Society 1, no. 2 (June 1, 1987): 125–51. https://doi.org/10.1177/0891243287001002002.

[72] Wing, Coady, and Thomas D. Cook. "Strengthening the Regression Discontinuity Design Using Additional Design Elements: A Within-Study Comparison." Journal of Policy Analysis and Management 32, no. 4 (2013): 853–77.

[73] World Bank Open Data. "World Bank Open Data." Accessed January 12, 2024. https://data.worldbank.org.

[74] Zhang, Yinjunjie, and Robert Breunig. "Female Breadwinning and Domestic Abuse: Evidence from Australia." Journal of Population Economics 36, no. 4 (October 1, 2023): 2925–65. https://doi.org/10.1007/s00148-023-00975-9.

Main Tables and Figures

Tables

Table 1: Summary Statistics

Variables	N	Mean	SD	p25	p50	p75	Min	Max
Common law	110113	0.45	0.50	0.00	0.00	1.00	0.00	1.00
Deforestation rate	110113	4.76	9.58	0.00	0.39	4.70	0.00	94.53
Adult literacy rate	109967	67.36	18.74	53.90	72.40	82.00	27.30	94.00
% Rural population	109967	54.91	14.75	46.00	54.00	64.00	9.00	86.00
Property right	97661	2.40	0.64	2.00	2.50	3.00	1.00	4.00
% Female in agriculture	109967	52.25	19.08	35.00	55.00	66.00	10.00	94.00
Muslim	110113	0.27	0.44	0.00	0.00	1.00	0.00	1.00
Malaria Suitability	106754	0.73	0.39	0.44	1.00	1.00	0.00	1.00
Elevation	110113	674.00	497.70	299.67	546.56	1013.67	-702.00	4623.75
Agricultural suitability	109657	0.37	0.27	0.13	0.34	0.54	0.00	1.00
Sea (distance)	110113	607.34	431.52	230.57	545.42	938.13	0.11	1735.68
border (distance)	110113	178.65	218.80	48.51	117.73	226.61	0.00	1483.29
Population (log)	110113	2.21	1.79	0.88	2.30	3.52	-5.20	9.77
Diamond	110113	0.00	0.06	0.00	0.00	0.00	0.00	1.00
Petroleum	110113	0.01	0.12	0.00	0.00	0.00	0.00	1.00
Water	110113	0.12	0.33	0.00	0.00	0.00	0.00	1.00
Rule of law	110113	-0.97	0.65	-1.45	-1.02	-0.51	-2.20	0.62
Corruption	110113	-0.81	0.59	-1.16	-0.88	-0.65	-1.66	0.81

Note: The data is from several sources, including Michalopoulos and Papaioannou (2013), Hansen et al. (2013), The Guardian, and the World Bank Indicator dataset. For the purpose of this analysis, countries are categorized as Muslim if they have a population where more than 50% of the individuals identify as Muslim. The table above shows the mean, standard deviation, 25th, 50th, and 75th percentile, mean and max of all the variables in the dataset.

Table 2: Differences Between Civil Law and Common Law Countries

	Civil law	Common law	Difference	pval
Deforestation rate	5.81	3.46	2.35	0.0
Adult literacy rate	61.99	73.96	-11.97	0.0
% Rural population	55.87	53.72	2.15	0.0
Property right	2.41	2.39	0.01	0.0
% Female in agriculture	60.35	42.29	18.06	0.0
Muslim	0.26	0.28	-0.02	0.0
Malaria Suitability	0.84	0.60	0.24	0.0
Elevation	600.97	763.77	-162.80	0.0
Agricultural suitability	0.35	0.38	-0.03	0.0
Sea (distance)	625.34	585.47	39.87	0.0
Border (distance)	195.57	157.92	37.65	0.0
Corruption	-0.88	-0.72	-0.17	0.0
Rule of law	-1.07	-0.85	-0.21	0.0

Note: Contrary to my initial assumptions, deforestation rates seem to be higher in civil law countries compared to common law countries. Interestingly, the level of property rights is also slightly stronger in civil law countries than in common law countries. Furthermore, a larger proportion of women are employed in agriculture in civil law countries than in their common law counterparts. As expected, levels of corruption are observed to be higher in civil law countries compared to those under common law systems.

Table 3:

Dependent variable: **log(deforestation + 0.01)**

Variables	(1) Linear b-dist	(2) Square b-dist	(3) Cubic b-dist	(4) Distance <100 km	(5) Distance <50 km	(6) No Muslim
Common Law	-0.479**	-0.488**	-0.435**	-0.399*	-0.324*	-0.767***
	(0.197)	(0.202)	(0.207)	(0.211)	(0.182)	(0.250)
Geographical control	Y	Y	Y	Y	Y	Y
Country level controls	Y	Y	Y	Y	Y	Y
Linear Distance	Y	Y	Y	Y	Y	Y
Square Distance	N	Y	Y	Y	Y	Y
Cubic Distance	N	N	Y	N	N	N
Ethnicity FE	Y	Y	Y	Y	Y	Y
Region FE	Y	Y	Y	Y	Y	Y
Constant	-1.357	-1.447	-1.449	-1.056	-1.170	-1.960
	(1.024)	(0.995)	(1.001)	(1.029)	(1.065)	(1.163)
Observations	94,104	94,104	94,104	41,735	23,940	65,687
R-squared	0.776	0.776	0.776	0.785	0.792	0.655

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: The standard errors are clustered according to ethnicity and country. All data in this analysis have ethnicity and region fixed effects. The pixel level variables controlled for in the model are malaria suitability, elevation, agricultural suitability, proximity to the sea and the capital city, logarithm of population size, and the presence of diamond and petroleum mines as well as water bodies. While country-level controls, that is adult literacy rates, property rights index, and the proportion of the rural population.

Figures

Figure 3:

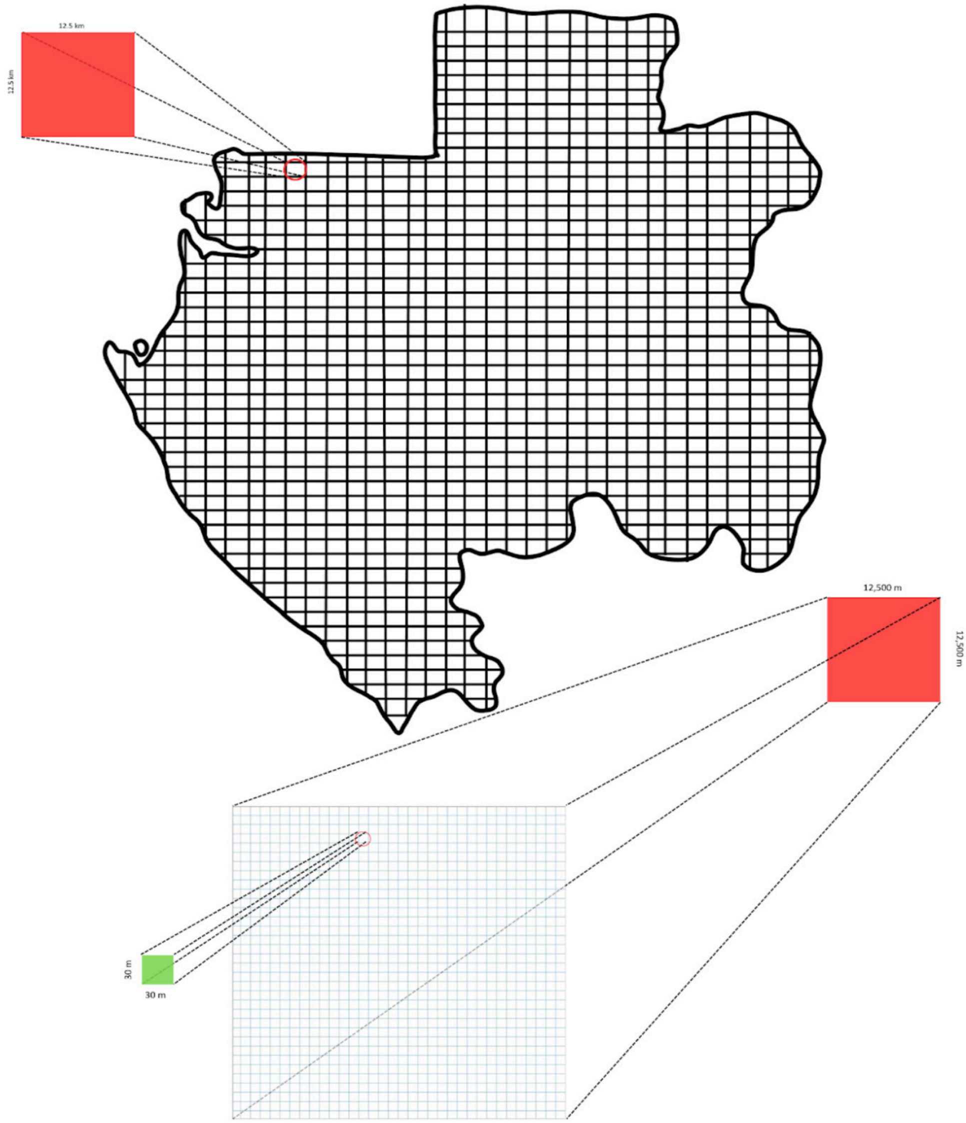
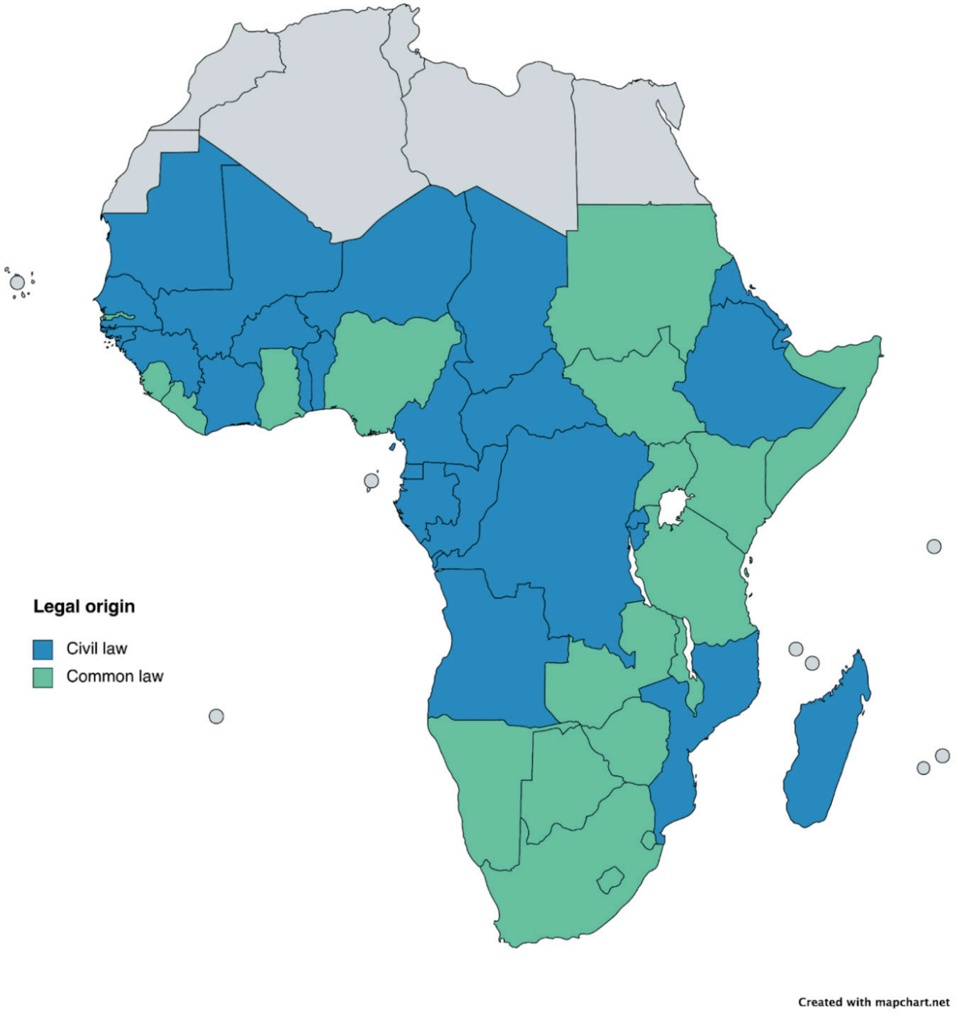


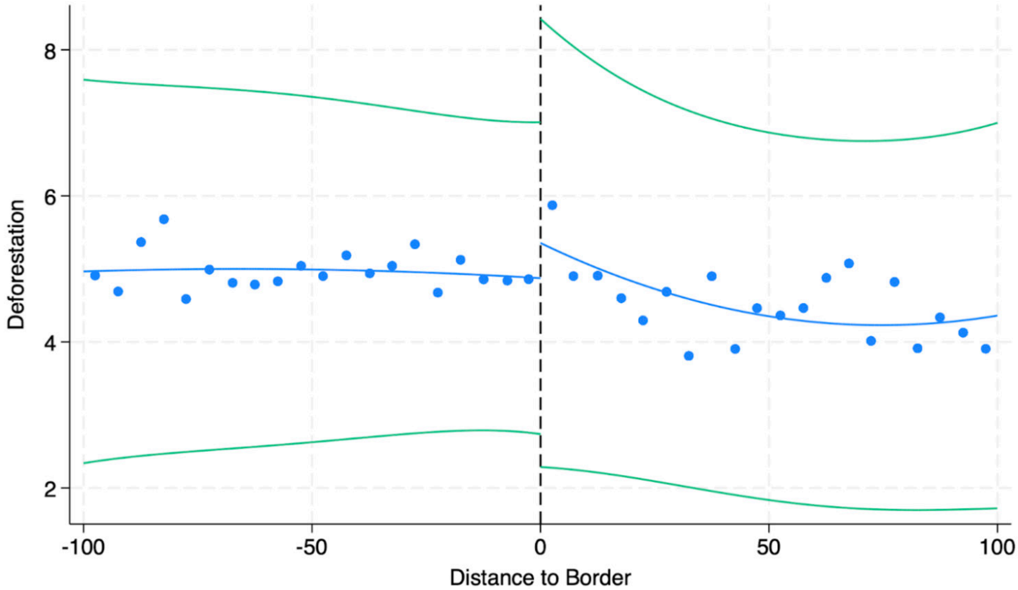
Figure 4:



Civil law countries: Angola, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Dem. Rep., Congo, Rep, Côte d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Guinea, Guinea-Bissau, Madagascar, Mali, Mauritania, Mozambique, Niger, Rwanda, Senegal, Togo.

Common law countries: Botswana, Eswatini, Gambia, The, Ghana, Kenya, Lesotho, Liberia, Malawi, Namibia, Nigeria, Sierra Leone, Somalia*, South Africa, Sudan, Tanzania, Uganda, Zambia, Zimbabwe

Figure 5: Regression Discontinuity at 100 km



Note: This graph depicts a regression discontinuity design comparing deforestation rates across a border, with civil law on the left (negative distance) and common law on the right (positive distance). The overlapping of standard errors (green lines) suggests that the difference in deforestation rates between civil law and common law countries may not be statistically significant at the border.

Appendix

Table 1A:

Type of property default regimes	**Definition**	**Administration of property within marriage**	**Division of property on divorce**	**Inheritance of marital property by wife on intestate death of husband**	**Legal origin**
Community of property	Property acquired during marriage is owned jointly by husband and wife (except gifts or inheritance earmarked for either spouse).	Consent of both husband and wife is required on joint assets (not on separate property).	Joint assets acquired during marriage (excluding separate property, such as gift or bequests) are divided 50-50.	Wife keeps separate property acquired before marriage and inherits 50 percent of joint property and the husband's separate property is part of the husband's estate and may (or may not) go to the wife.	Civil law
Separate property	Each spouse acquires and owns property as individuals.	Each spouse administers his or her own property.	Each spouse receives 100 percent of his or her own property. No presumption is made of the other spouse unless he or she can show that financial contributions were made.	No presumption is made that a wife is entitled to any of her husband's property.	Common law

Table Adopted from Hallward-Driemeter and Hasan (2012).

Note: Around the world, reforms in default property rights occurred around the 1960s when most African countries were gaining independence and these reforms were not replicated in most African countries (Anderson 2018).

Table 2A:

Dependent Variable: Deforestation rate (%)

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Linear bdist	Square bdist	Cubic bdist	Distance <100 km	Distance <50 km	No Muslim
common	-1.010	-1.126	-1.033	-0.867	-0.633	-2.488**
	(1.068)	(1.081)	(1.132)	(1.221)	(1.106)	(1.183)
Ethnicity FE	Y	Y	Y	Y	Y	Y
Region FE	Y	Y	Y	Y	Y	Y
Geographical controls	Y	Y	Y	Y	Y	Y
Border Distance	Y	Y	Y	Y	Y	Y
Square Border Distance	N	Y	Y	Y	Y	Y
Cubic Border Distance	N	N	Y	N	N	N
Constant	4.576***	4.516***	4.535***	4.796**	4.357*	5.397**
	(1.565)	(1.587)	(1.586)	(1.860)	(2.225)	(2.012)
Observations	94,104	94,104	94,104	41,735	23,940	65,687
R-squared	0.487	0.487	0.487	0.528	0.541	0.437

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: The outcome presented aligns with the findings from Table 3, with the addition of country-level controls, that is adult literacy rates, property rights index, and the proportion of the rural population.

Table 3A: Log Deforestation Rate for Non-Muslim Countries

	(1)	(2)	(3)	(4)
Variables	Linear b_dist	Cubic b_dist	Distance 100 km	Distance 50 km
Common	-0.832***	-0.653**	-0.499**	-0.362**
	(0.254)	(0.244)	(0.201)	(0.173)
Constant	-1.887	-1.962	-1.490	-0.800
	(1.208)	(1.179)	(1.045)	(1.057)
Observations	65,687	65,687	28,825	16,720
R-squared	0.655	0.656	0.714	0.731

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: The table presented above details the findings for countries with a non-Muslim majority population. It's important to note that the Quadratic distance function has been addressed in the main results section. This table exclusively features the log deforestation rate, and all reported results are statistically significant. These findings have been adjusted for various factors, including geographical and country-level variables, as well as regional and ethnic influences, with standard errors clustered at both ethnic and country levels.

Table 4A: Absolute Deforestation Rate for Non-Muslim Countries

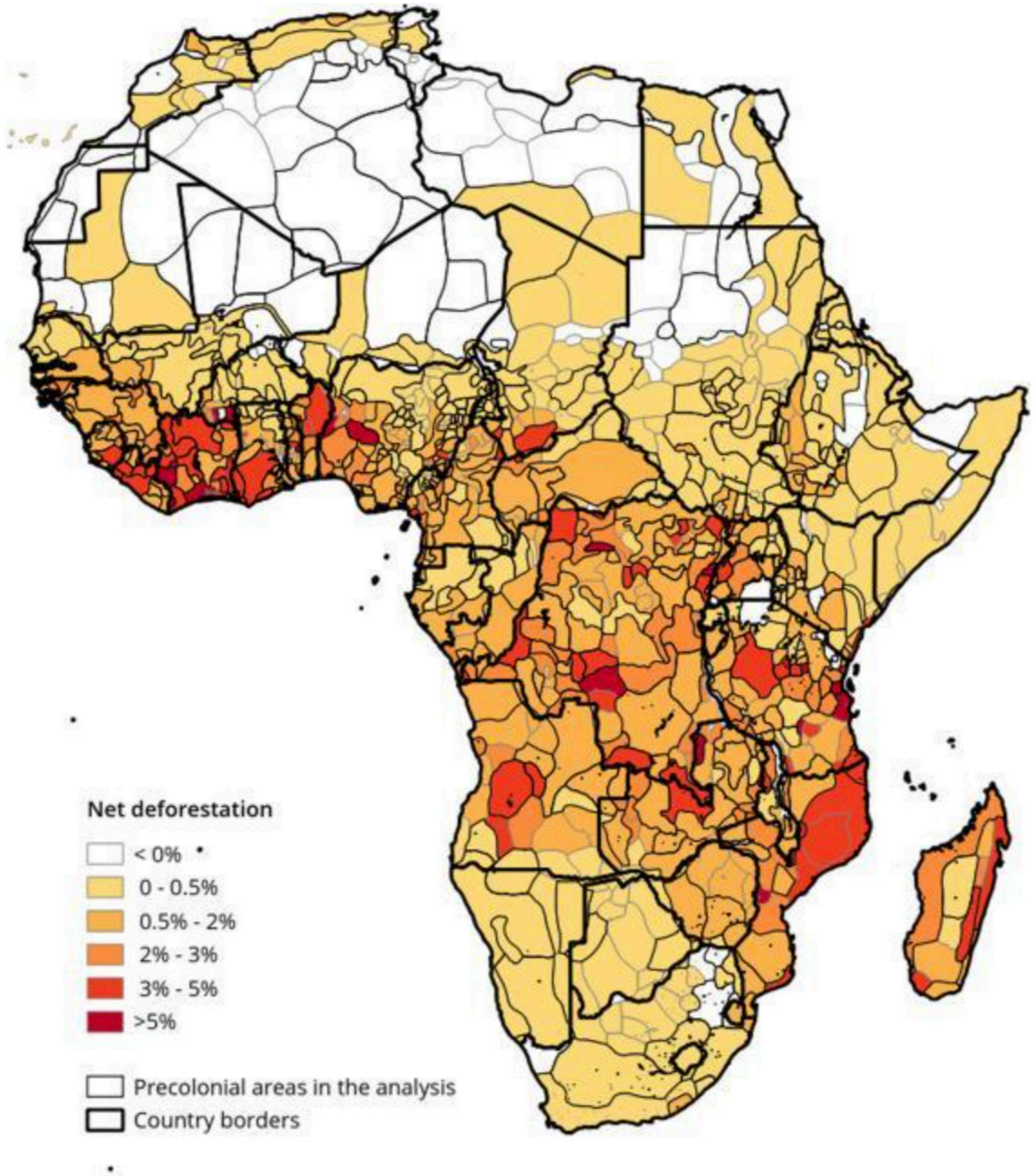
	(1)	(2)	(3)	(4)
Variables	Linear b_dist	Cubic b_dist	Distance 100 km	Distance 50 km
Common	-2.550**	-2.096	-1.829	-1.548
	(1.197)	(1.237)	(1.290)	(1.029)
Constant	-1.013	-1.012	-0.450	-1.507
	(4.072)	(4.090)	(4.357)	(4.745)
Observations	65,687	65,687	28,825	16,720
R-squared	0.437	0.437	0.504	0.523

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

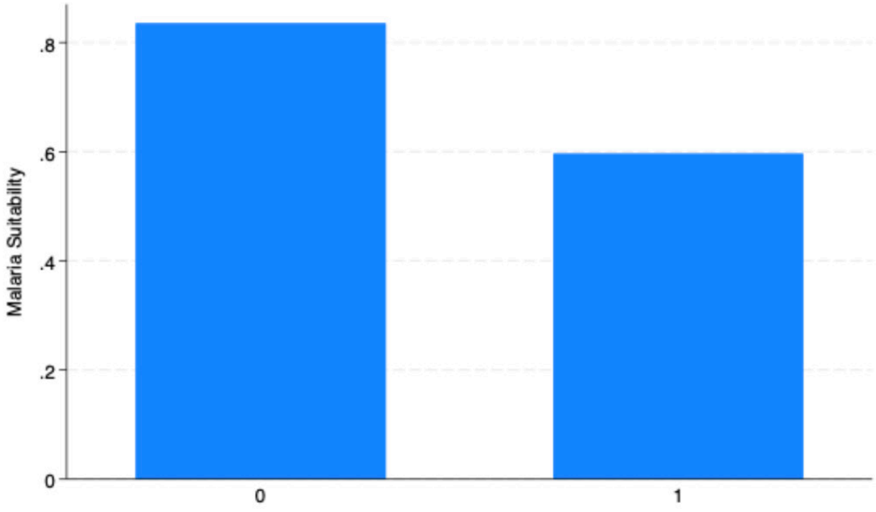
Note: The result for non-Muslim majority countries lose the statistical significance for cubic and limitation on distances. However, the results maintain the same trends as table 3A.

Figure A1: Pre Colonial Institutions and Deforestation (Larcom et al. 2013)



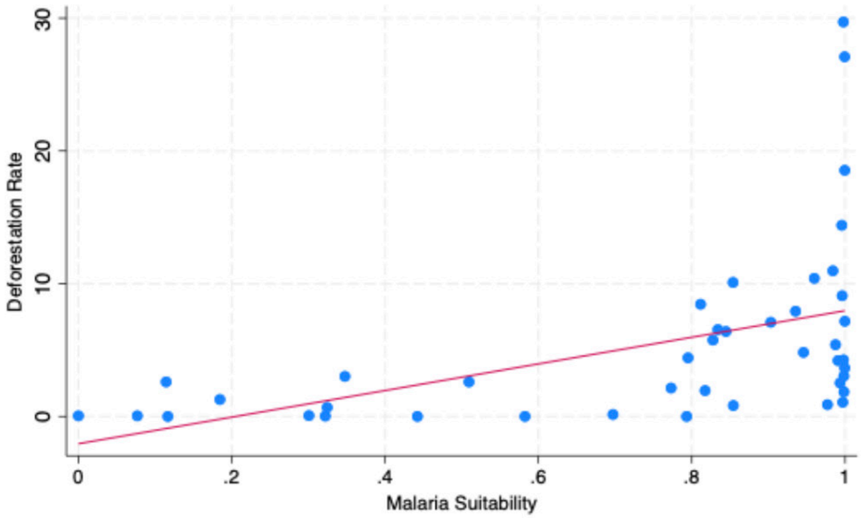
Note: The study finds that in regions where local leaders were selected based on their social status, there tends to be weaker governance in both local leadership and forest management. This connection between deforestation and pre colonial institutions highlights the significance of accounting for these ethnic variations in our study.

Figure A2: Malaria Suitability and Legal Origin



Note: Malaria suitability is higher in civil law countries than in common law countries. Therefore, deforestation is more favorable in common law countries where the burden of malaria is significantly lower.

Figure A3: Malaria Suitability and Deforestation



Note: However, the graphical analysis of my data indicates that countries with greater malaria suitability tend to have higher rates of deforestation.

Figure A4: Petroleum and Deforestation

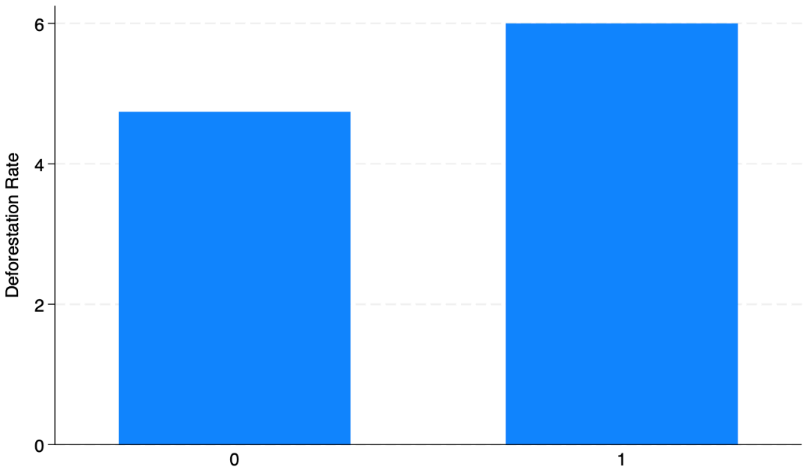


Figure A5: Diamond and Deforestation

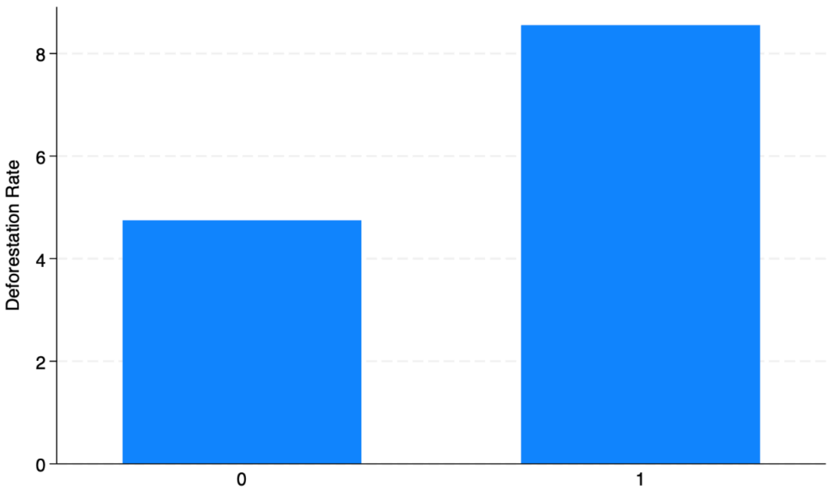
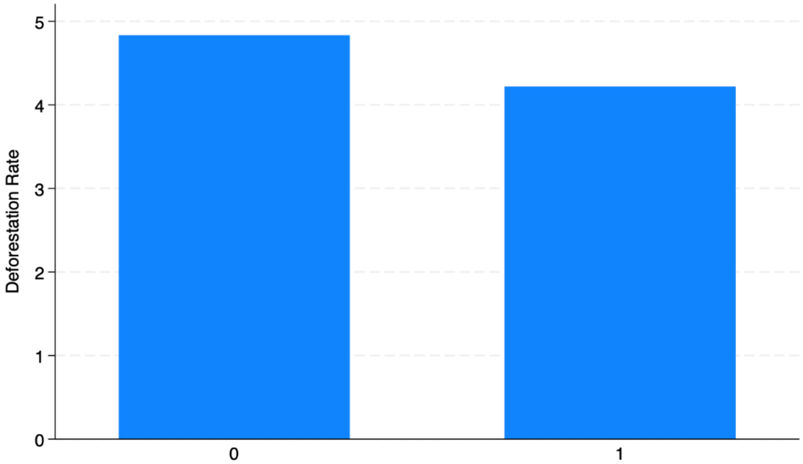
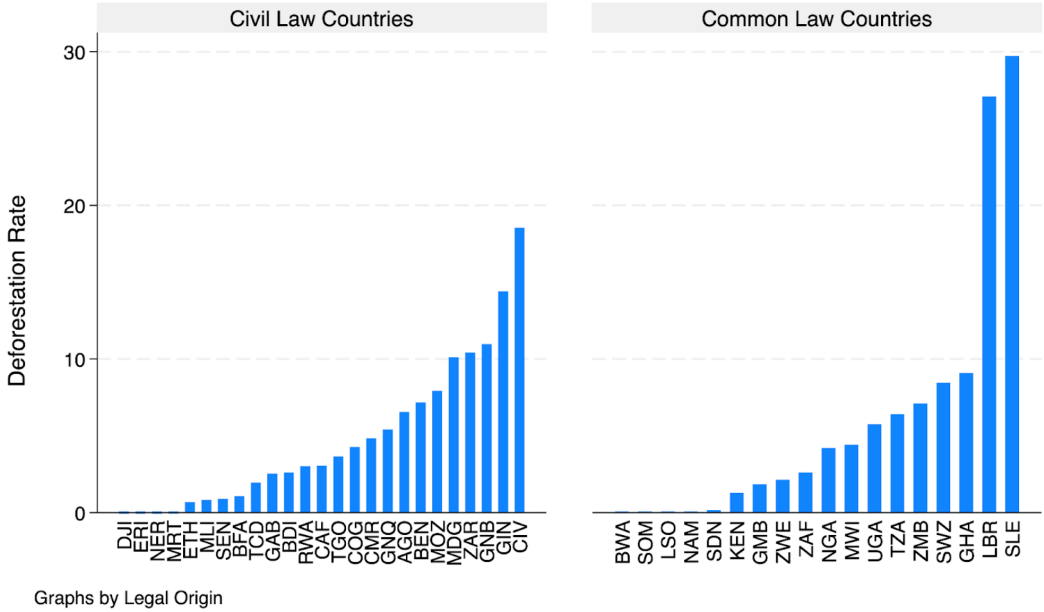


Figure A6: Water and Deforestation



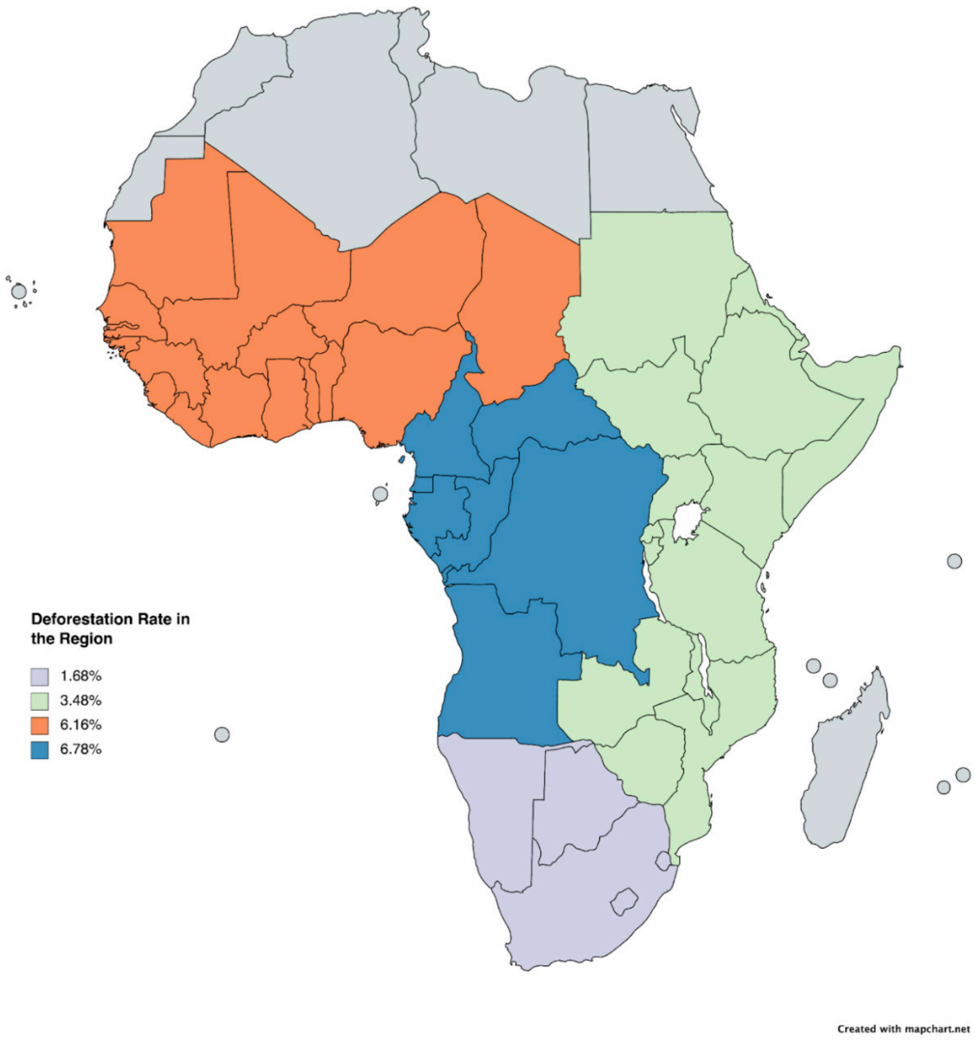
Note: Figures A4, A5, and A6 illustrate the correlations between deforestation and the presence of petroleum, diamonds, and water bodies within a given area, respectively. Each figure consistently aligns with anticipated trends, indicating that regions with mining and petroleum fields exhibit higher rates of deforestation, while those with water bodies demonstrate lower rates of deforestation.

Figure A7:



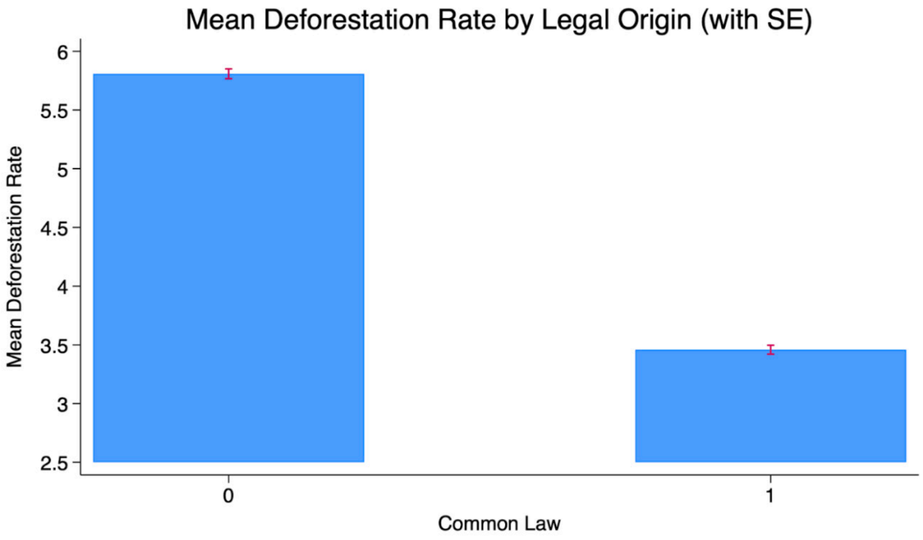
Note: In common law countries, Sierra Leone and Liberia have very large deforestation. However, all the other countries have a deforestation rate lower than 10%.

Figure A8:



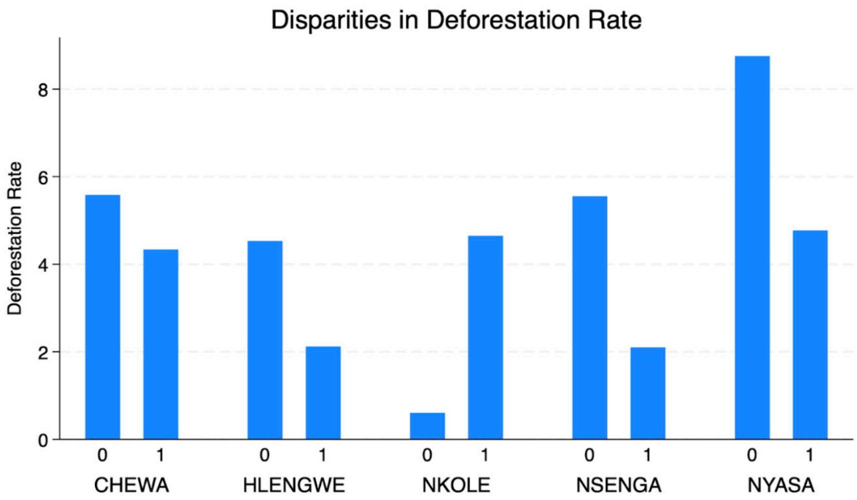
Note: There exists a notable regional disparity in deforestation rates. Countries in the South exhibit the lowest average deforestation at just 1.68%, whereas Western and Central countries show significantly higher averages of 6.16% and 6.78%, respectively. Eastern countries, in contrast, have a moderately lower deforestation rate of 3.48%

Figure A9:



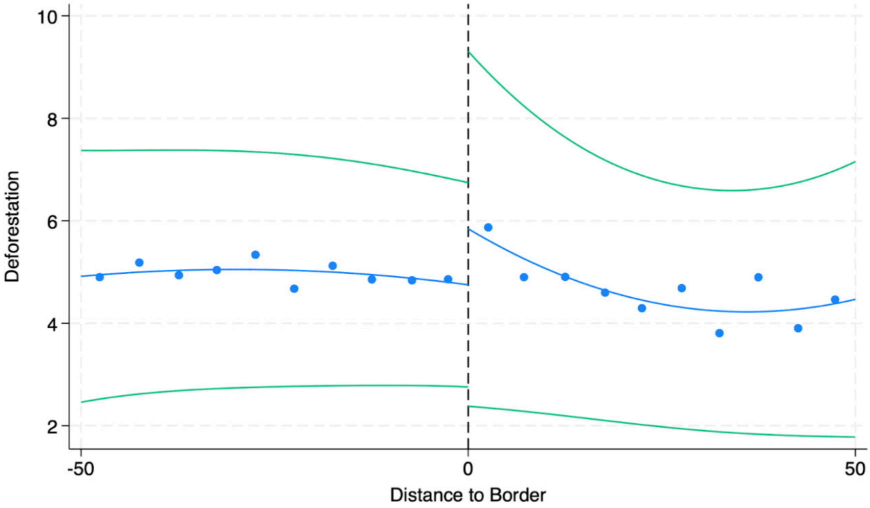
Note: Civil law countries have a mean deforestation rate of 5.81 while common law countries have a mean deforestation rate 3.46. There is a clear and significant difference of 2.35.

Figure A10:



Note: For most tribes, the civil law (0) shows a higher deforestation rate than the common law (1). However, the Nkole tribe's reverse trend indicates that the relationship between legal systems and deforestation is not uniform across all tribes.

Figure A11:

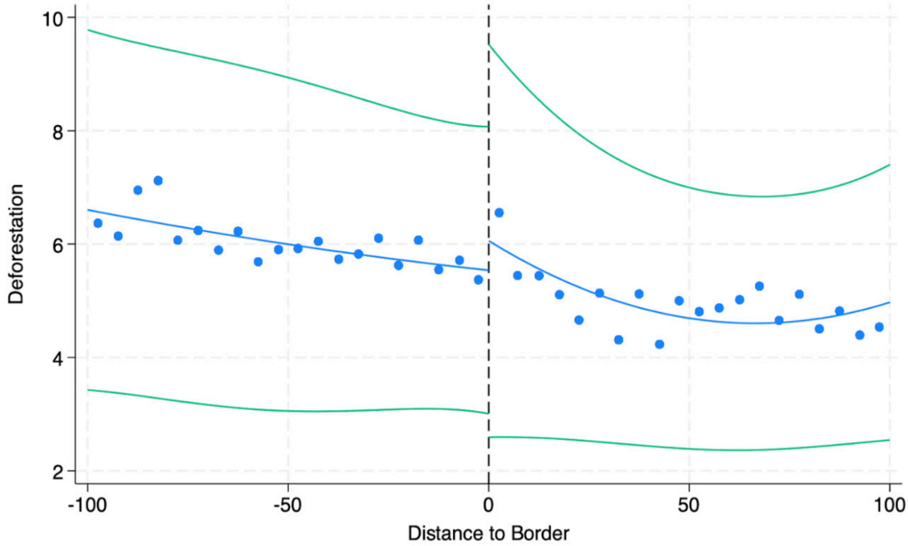


Note: Similar to Figure 5, this graph also depicts a regression discontinuity design comparing deforestation rates across a border, with civil law on the left (negative distance) and common law on the right (positive distance). It shows a similar trend to that of Figure 5 where the deforestation rates are higher on the civil law side and decrease as one moves towards and into the common law region.

Figure A12:

Note: Burkina Faso, Chad, Djibouti, Gambia (The), Guinea, Mali, Mauritania, Niger, Senegal, Sierra Leone, Somalia, Sudan

Figure A13:



Note: The trends highlighted in take 5 persist although the deforestation rate in civil law countries are higher and increases as it moves away from the national border.

Figure A14:

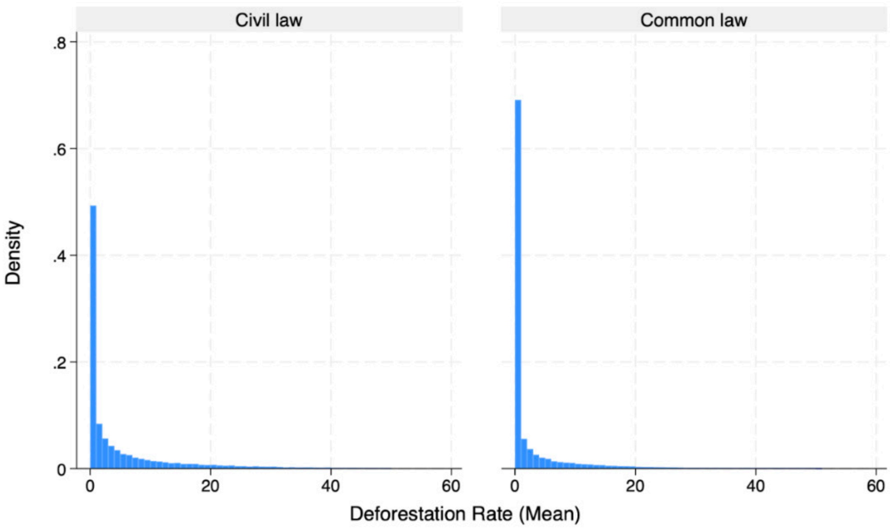
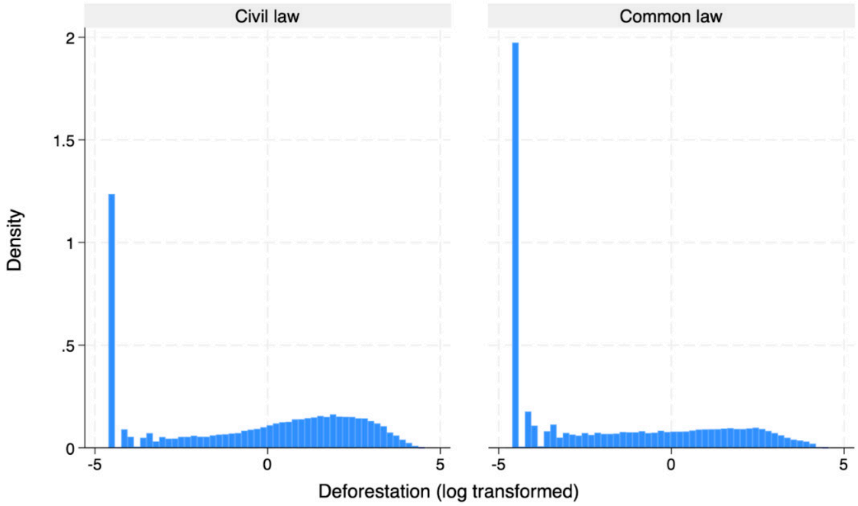


Figure A15:



Note: Both legal systems show a prevalence of low deforestation rates, as evidenced by the pronounced spikes at the lower end of the distribution in both figures above. Figure A14 shows the right-skewed nature of the data, with a notable proportion of pixels in civil law countries experiencing very high deforestation rates. These distributions indicate that while deforestation is generally low across pixels, civil law countries experience a higher deforestation rate than common law countries.

Variable Description

Variable Name	Description	Source
Common	This binary indicator variable identifies whether a country operates under a common law or civil law legal system.	La Porta et al. (2008)
Deforestation Rate	Represented as a percentage, this variable ranges from 0 to 100 and indicates the rate of deforestation in each pixel.	Hansen et al. (2013)
Water Indicator	A dummy variable that takes the value of 1 when some water body(river, lake, or other stream) falls in each pixel or 0 otherwise.	Michalopoulos & Papaioannou (2013)
Population Density	Log(population density sq. km. in 2000).	Michalopoulos & Papaioannou (2013)
Elevation	The average elevation (in kilometers) for each ethnicity, country, or pixel.	Michalopoulos & Papaioannou (2013)
Suitability	A measure of the average quality of land for cultivation within each country-ethnicity homeland or pixel. It is an index composed of climatic and soil suitability factors for farming.	Michalopoulos & Papaioannou (2013)
Malaria Stability	An average indicator of malaria prevalence within each ethnicity, country or pixel. This index considers factors such as mosquito prevalence and type, human biting rate, daily survival rate, and incubation period.	Michalopoulos & Papaioannou (2013)
Distance to the Capital City	This variable is the Distance to the Capital City normalized by the maximum distance to the capital within the same country.	Michalopoulos & Papaioannou (2013)
Distance to the Sea Coast	Measured in thousands of kilometers, this variable represents the geodesic distance from the centroid of each ethnicity-country or pixel to the nearest coastline.	Michalopoulos & Papaioannou (2013)

Variable Name	Description	Source
Distance to the National Border	The geodesic distance, in thousands, of kilometers from the centroid of each ethnicity-country or pixel to the nearest national border.	Michalopoulos & Papaioannou (2013)
Petroleum	A binary indicator variable assigned a value of one if a petroleum mine is present in the region (or pixel) of ethnic group i in country c.	Michalopoulos & Papaioannou (2013)
Diamond	A binary indicator variable assigned a value of one if a diamond mine is present in the region (or pixel) of ethnic group i in country c.	Michalopoulos & Papaioannou (2013)
Water	A binary indicator variable assigned a value of one if a water body (river, stream, lake, etc.) is present in the region (or pixel) of ethnic group i in country c.	Michalopoulos & Papaioannou (2013)
Adult literacy rate	Adult (15+) female literacy rate in countries across SSA.	World Bank Database
Rural Population	Percentage of total population living in rural areas as defined by national statistical offices.	World Bank Database
Property Right	An index that evaluates how effectively a legal system facilitates private economic activity by reliably respecting and enforcing property and contract rights.	World Bank Database
Employment in Agriculture	Percentage of total population (modeled ILO estimate) working in agriculture.	World Bank Database
Region	The United Nations' classification of subregions in Africa	UNSD 2024
Muslim	An indicator variable showing if a country is muslim majority	The Guardian