Land I: Incentives and Effort
Land II: Limited Liability, Risk Aversion, and Property Rights

14.740x: Foundations of Development Policy

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Farm size and productivity: observed relationship

- Stylized fact in size productivity differences : Small farms more productive than large farms ▸ Example
  - Profit-Wealth ratio and weather variability (monsoon outset is a measure of the risk faced by the farmer) ▸ Graph
    - The Profit-Wealth ratio is always greater for small farmers
    - Small farmers' profit is much more risky than large farmers'

Why is this surprising: argument for increasing returns

- Arguments for increasing returns
  - Technology with fixed costs (tractors, etc..)
    - Larger farmers have better access to capital (evidence in a few lecture)
    - Larger farmers have better access to politically allocated inputs (evidence from Africa in a book by Bates "Market and states in tropical Africa").
    - The best farmer will have more land...
  - Mitigating factors:
    - Rental markets in farm machinery
    - Technological change in not very rapid. Saviness not that important.

Why do we see this relationship?

- Agency problems: large farms are cultivated by hired labor, which has fewer incentive to work hard. Small farms are owner cultivated.
    - Selection: risk averse farmers are sharecroppers
    - Land quality: land that is sold is of poorer quality.

Binswanger and Rosenzweig

- Use ICRISAT data: very detailed panel (repeated observation for every household) data from India.
  - Some individuals cultivate both an owner-operated plot and a rented plot. Biswanger and Rosenzweig compare the inputs they apply on their own plot and the rented plots, and the overall productivity of both plots.

$$\Pi_{ij} = \alpha + \beta R_{ij} + \eta_i + \upsilon_{ij},$$

  - where Π_{ij} is farmer's i profit on plot j, and R_{ij} indicate whether the plot is rented. η_i is the unoberved (but fixed) characteristics of the farmers (risk aversion, quality, etc...). We think that η_i and R_{ij} may be correlated, but, for a minute, not υ_{ij} and R_{ij}.

Biswanger and Rosenzweig

- Control for the individual fixed effect to compare plots within individual's. So for example, for all the farmers that cultivate two plots of land, we can run the regression:

$$\Pi_{i2} - \Pi_{i1} = \beta(R_{i2} - R_{i1}) + \upsilon_{i2} - \upsilon_{i1},$$

  - Biswanger and Rosenzweig find a strong negative β. What does this suggest? What could be the remaining problem?
  - Shaban (1987) use the same data, but control in addition for plots quality. He also looks at the all the inputs that people put on their plots (does this remind you of another paper we have seen?). ▸ table
  - Shaban finds that individual work 40% more on their own land (controlling for land size) and that the productivity is 15% to 30% higher on own land than on rented land (with or without controling for productivity).

Sharecropping and incentives

- So it looks like agency problems plays a role
  - But cannot the owner of the land not give the right incentive to the farmers?
  - Limited liability
  - Risk aversion

BGG: A simple model of sharecropping

- There is a landlord who own two plots of land but can only cultivate 1
  - He hires a tenant to farm the other plot
  - Cultivation effort is denoted by e.
  - The landlord cannot observe e.
  - Effort is costly to the tenant: $\frac{1}{2}ce^2$
  - Tenant's VNM utility function: $u(c)$
  - Expected utility maximizer

BGG

- Two things can happen:
  - with probability e: Output is H
    - with probability $1 - e$: Output is 0
  - The tenant has outside option $\underline{w}$
  - The tenant and landlord write a contract which specifies a payment to the tenant
    - a payment h if output is H
    - a payment l if the output is 0

Optimal choice of effort

- The landlord chooses e to maximize $eH + (1 - e)0 - \frac{1}{2}ce^2$
  - In the absence of agency constraint, what is the solution for effort and why?

No limited liability

- Work sequentially: given h and l, what is the tenant's effort?
  - Tenants want to maximize income minus the cost of effort: $eh + (1 - e)l - \frac{1}{2}ce^2$
  - What is the solution for e given h and l?
  - How do we need to fix h and l to incite the tenant to choose the optimal effort $\frac{H}{c}$?
  - $l =$
  - $h =$
  - This contract is a *fixed rent contract*.
  - How is the rent, R, chosen?
  - Tenant has to agree to work with landlord: he has to receive at least $\underline{w}$. $\rightarrow$ exercise: calculate R

Solution with Limited Liability

- Imagine that the tenant cannot receive negative payment: *limited liability*.
  - What will l be?
  - What will e be?
  - What will the output be?
  - How does it move with h?
  - Maximization problem of the landlord: Maximize his income.

$$\max \; e_{tenant}[H - h]$$

$$\max \; \frac{h}{c}[H - h]$$

    - What is the optimal h now?
    - What is the output?
    - How does the output compare to the optimal output?
    - What is the difference h - l?
    - How does it compare to the case without limited liability?
    - Why is the effort smaller than the optimal effort?

The role of the outside Option

- Remember that the tenant can choose to work somewhere else and will receive a utility $\underline{w}$. How does it modify the contract chosen above?
  - Tenant's utility under the contract:

$$\begin{aligned} & \frac{h}{c}h - \frac{1}{2}c(\frac{h}{c})^2 \\ = \quad & \frac{1}{2}\frac{h^2}{c} = \frac{1}{8}\frac{H^2}{c} \end{aligned}$$

  - If $\frac{1}{8}\frac{H}{c}^2 \geq \underline{w}$, they can choose this contract: Note that the contract does not depend on $\underline{w}$?
  - if $\frac{1}{8}\frac{H}{c}^2 < \underline{w}$, they have to pick a contract which will give at least $\underline{w}$ to the tenant Pick h such that:

$$\frac{1}{2}\frac{h^2}{c} = \underline{w}$$

Outside option

- Solution
  - $h=$
    - $e=$
  - e is always an increasing function of $\underline{w}$
  - output is always an increasing function of $\underline{w}$
    $\rightarrow$ increasing the tenant outside option increases productivity

Risk of dismissal

- Note that in this contract the tenant earns *rent* if we are in the case where the participation constraint is not binding.
    - Landlord can induce higher effort by threatening to fire the tenant in case of low output.

Implications

What does that imply for

- The effort chosen by the tenant versus the landlord?
- The relation between land-size and productivity assuming that some people own 1 unit of and some 2?
- The effect of redistributing land on productivity?

Does land reform work? Banerjee-Gertler-Ghatak (2002)

Banerjee, Gertler, Ghatak study a *tenancy reform* = improvement in the rights of tenants. It differs from a traditional land reform (redistribution of land). Land is not redistributed. The tenant is offered the *security of tenure* = if he registers, he cannot be evicted by the landlord, as long as he pays 25% of the output to the landlord

Consequences of the reform on the tenant

1. Bargaining power effect
   - Tenant and landlord negotiate on the share
   - Before, what would happen to the tenant if he disagreed with the landlord?
   - After, what can happen to him?
   - What are the consequences of this on the share of the tenant?
   - Is it good or bad for productivity?
2. Security of tenure effect
   - What positive effect does it have on productivity?
   - What negative effect does it have on productivity?
   - The expected effects of the reform
     1. Reform $\rightarrow$ bargaining power $\rightarrow$ improvement in share $\rightarrow$ improvement in productivity
     2. Reform $\rightarrow$ security of tenure $\rightarrow$ improvement in productivity (?)

Empirical analysis of the reform

- Left front government came to power in 1977
  - Started registration camps in villages (officials came to help tenants register)
  - Faced some difficulties = flood, landlords' opposition
    $\rightarrow$ registration progressed more slowly than expected and was still continuing in early 1990s.
  - Study use difference in difference.

Results

- Security and share of output
  - From a retrospective survey: 80% said that landlord used eviction threats in the pre-reform period and 30% claimed that they (or their fathers) were actually threatened. 96% said it was difficult or impossible to evict now.
    - share of tenants getting more than 50% of output went up from 17% to 39%.

Productivity: Bangladesh vs West Bengal

- Neighboring country but no reform
  - Difference in difference

    ▸ graph ▸ table
  - Possible Issues with this analysis, and what do they do to try to address it?

Productivity: Within West Bengal

- Districts had different registration rates at different times. At any given point, was productivity higher in the districts which had more registered tenants?

$$y_{dt} = \alpha_d + \lambda_\epsilon + \beta b_{dt} + \gamma X_{dt} + \epsilon_{dt}$$

b_{dt} = number of registered tenants
$X_d t$ = other district-time varying variables
γ = effect of other district-firm varying variables on productivity

  - Results. ▸ table higher registration is associated with faster growth in yield.
  - Identification issues?
  - Note: Mookherjee and Bardhan (2009): observe that people who actually got registered are no more productive. Explanations: spillover, selection. Having the option to register may be sufficient.

Other sources of inefficiencies: Risk Aversion

- Drop limited liability
  - Now insurance is traded off against incentives: A risk neutral landlord and a risk-averse tenant, classical moral hazard problem (Stiglitz; Holmstrom)
  - The delicate part is to model the occupational choice part (who will select as landlord and who will select as farmer). As we saw earlier, this is important to analyze the effect of land reform.
  - If there is co-insurance (everybody is risk averse, more or less risk averse) the analysis can be very complicated.

A model of occupational choice: Costly verification of output

- Suppose output is costly to verify. Specifically one unit of labor can verify the output of N plots of land.
  - Assume everyone has one unit of labor and that this unit is indivisible: This unit can either cultivate 1 unit of land or verify output on N plots of land.
  - Finally assume that the total output of the N plots that the verifier verifies is unobservable to others: no one insures the person who verifies output.
  - Therefore there are three possible occupations
    1. Tenant: someone who farms 1 unit of land whose output is verified by the landlord and therefore can get insurance
    2. Landlord: someone who verifies output and insures others
    3. Yeoman farmer: someone who gets no insurance but farms 1 unit of land.

A model of occupational choice: Costly verification of output

- Suppose first risk-aversion is fixed: Everyone is CARA with potentially differing coefficients.
  - To simplify further, think of the case where one group of farmers is quite risk averse and the other is risk-neutral
  - And there are too few risk neutral people to cultivate all the land.
  - Who, in terms of risk-aversion will become
    - a tenant
    - a yeoman farmer
    - a landlord?
  - What are the implications for
    - Farm size and productivity?
    - And the effect of land redistribution?

Risk aversion and Wealth

- Now let risk-aversion vary with wealth (CRRA) and let people have identical utility functions but differing wealth
  - who becomes a tenant?
    - Farm size productivity?
    - The effect of land redistribution?

Two-sided moral hazard (Eswaran and Kotwal)

- A third model: two sided moral hazard, no limited liability, risk neutrality.
  - People have 2 unit of labor. They can use for either management or working.
  - Some people can only do management, some do only labor, some can do both.
  - Those who can do only labor need a manager and become tenant.
  - Those who can do only manager need labor and become landlord
  - Those who can do both become yeoman
  - Implications:
    - Farm size and productivity
    - The effect of land redistribution

Why land reform? (Banerjee, 2000)

Why redistribute land rather than money? As economists, we tend to think that money is better, since with money, the poor could buy land if they wanted to. So why land reform?

- The giving end: Getting land from the rural rich.
  - Common argument (1): land cannot flee to Switzerland, and cannot be hidden: easy to seize.. not clear this is true in practice
  - Common argument (2): redistributing land does not create distorsions, since it is a fixed asset (income taxation would reduce labor supply, but land does not). not clear this is true in practice.
  - Perhaps we want to tax the rural rich, and not the urban elite (entrepreneurs, etc...), for example because we want to foster industrialization. This does not seem to be important now, since recent examples have favored *market assisted* land reforms, whereby landlords are is compensated out of general tax revenues.

Why land reform?

- The receiving end: giving land to the rural poor.
  - Makes them more likely to migrate to the cities. But are cities really too large?
    - Land is an asset: can be used as collateral and therefore may generate extra value (Hernando de Soto). But why would illiquidity help.
    - Intrahousehold allocation issues. Perhaps money would be spent by the household head in alcohol etc... whether land will remain in the household. We should make it hard to sell the land then! This may be the most compelling argument in favor of land reform.

Beyond Land Reform: Property Rights

This discussion suggests that the discussion of land reform cannot be separated from a discussion of property rights, which are a core issue at the intersection of development and political economy. Two good summary of the literature: Udry Pande (institutions: a view from below) and Besley and Ghatak (Property Rights and Economic Development). Building on Besley (1995), Besley and Ghatak mention 4 channels why property rights matter:

- Expropriation risk: weak property right means that someone who invests may not get the fruit of their investment or effort (Besley; Hornbeck; Field; Di tella et al.)
- Weak property rights: people do costly things to defend their property (Field; Goldstein-Udry)
- Weak property rights: factors cannot easily be allocated to best user (e.g. through renting, or working within household) (Udry)
- Use of property in supporting other transaction: e.g. as collateral for loans (De Soto Argument) (Wang, 2008).

Besley, 1995

- One of the early papers on the effect of land rights on investment
  - Look at tree planting in Ghana
  - Household self report different rights on different plot (to sell, to rent, etc.), and there are rights with or without approval (from communities)
  - Two strategies for dealing with potential endogeneity of property rights:
    - hh fixed effects
    - instrument with plot characteristics (believable?)
  - Results a little ambiguous: significant in OLS, but disappear after IV+Fixed effect (large standard errors) ▸ OLS ▸ FE

Hornbeck, 2008

- Looks at exogenous variation of the ease of *enforcing* property rights.
  - Invention and introduction of barbed wire between 1880 and 1890
  - In places that did not have a lot of woods, make fencing much cheaper than what it was before.
  - Allows protection of fields against cows (and therefore proof that you had guarded your property)
  - DD approach: did productivity improved faster between 1880 and 1890 in counties that did not have a lot of wood, compared to counties that had a lot of wood ?
  - Find that average crop productivity increased 23% faster in non-wooded places than in wooded places between 1880 and 1890 ▸ Figure ▸ Table3 ▸ Table5

Field, 2007

- An example of costly action in response to weak property rights
  - Between 1996 and 2003 government in Peru issued property titles to 1.2 million urban households
  - Difference in difference strategy: Exploit timing of introduction of program across regions+ differences in pre-program ownership rights: using a single cross section she compares neighborhood that are already reached/not reached and squatters/non squatters.
  - Main variable of interest in 2007 paper: do people increase their labor supply? Why would we see something like that?
  - Results: People work more hours, and they are less likely to work from home. ▸ Table
  - Potential caveats?

Is there a collateral effect?

- Field and Torero (2006) use the same strategy as Field to look for an effect on access to credit, and find very little evidence of increase (on the other hand they do find much greater investment in the quality of the home, consistent with channel 1). ▸ repairs ▸ credit
    - Galiani and Schargrodsky look at the same question in Argentina, comparing squatters in Buenos Aires. There again, they find large effects on home investment, but little effect on access to credit,
    - Explanation for this failure: land titling reduces the value of land as collateral since it suggests that seizing the asset will be impossible...

Is there a collateral effect?

- Shing-Yi Wang (2008) looks at the effect of a program that allowed state employees in China who were renting their house the right to buy it at subsidized prices: find increase in entrepreneurship, in part because people could now leave state employment after they had bought their house (not the effect we are looking for) and in part because they were now able to use the real estate they were seating on as collateral.

From Development economics to political economy

- We have been looking mainly at the impact of land reform and property rights regulation
  - But those are outcomes of a political process.

TABLE 2: Farm-size productivity differences, selected countries

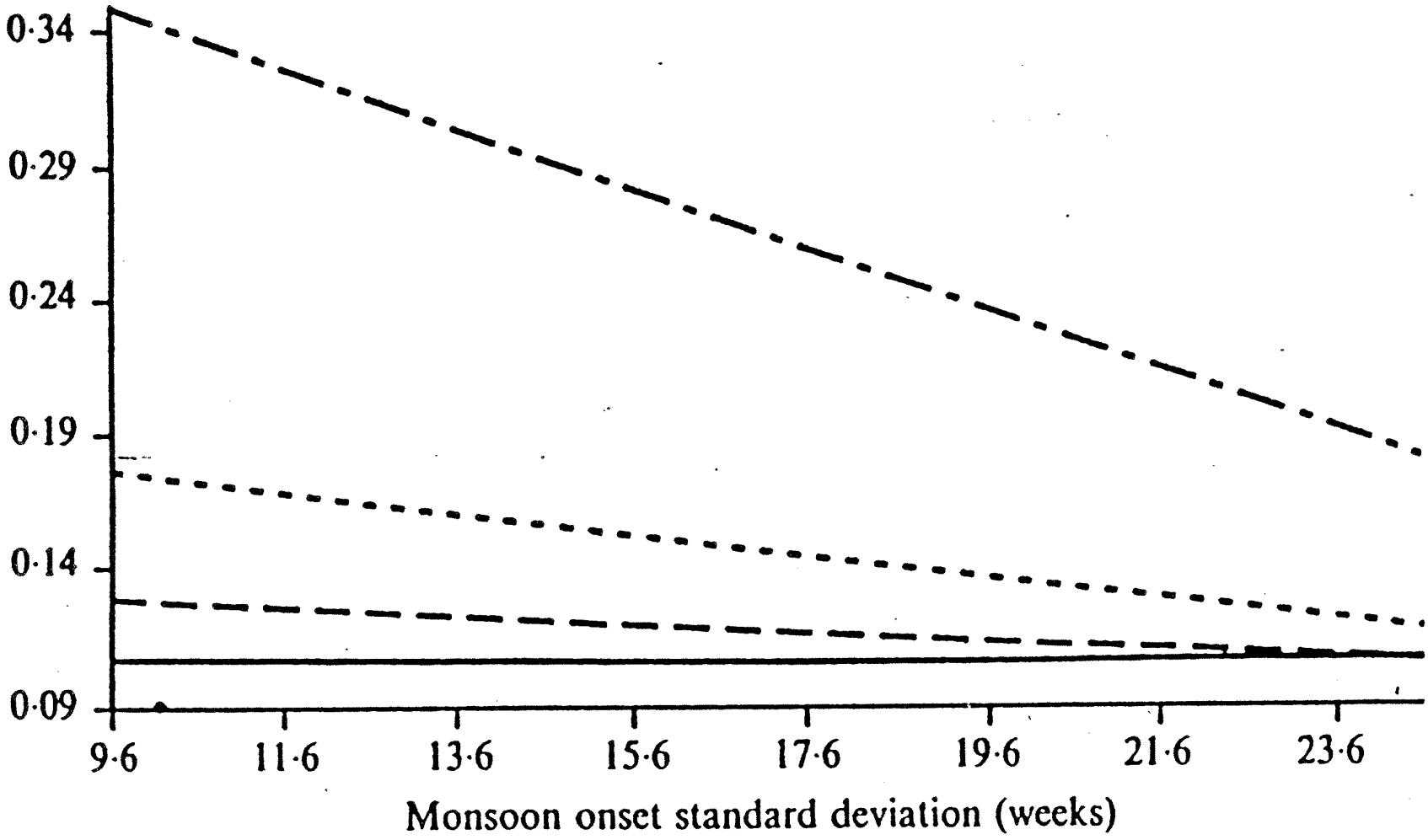
Farm size[a]	Northeast Brazil[b]	Punjab, Pakistan[c]	Muda, Malaysia[d]
Small farm (hectares)	563 (10.0-49.9)	274 (5.1-10.1)	148 (0.7-1.0)
Largest farm (hectares)	100 (500+)	100 (20+)	100 (5.7-11.3)

Notes:

[a]100 = largest farm size compared with second smallest farm size. Second smallest farm size used in calculations to avoid abnormal productivity results often recorded for the smallest plots.
[b]Table 4-1. Northeastern Brazil, 1973; Production per Unit of Available Land Resource, by Farm Size Group, p.46. Index taken using average gross receipts/areas for size group 2 (small) and 6 (large), averaged for all zones excluding zone F, where sugarcane and cocoa plantations skew productivity average for large farms.
[c]Table 4-29. Relative Land Productivity by Farm Size: Agricultural Census and FABS Survey-based Estimates Compared, (1968-9) p. 84. Index taken using value added per cultivated acre for second smallest size group and largest.
[d]Table 4-48. Factor Productivity of Muda River Farms by Size, Double Croppers, 1972-3 p. 117. Index taken from value added in agriculture/relong (0.283 ha = 1 relong).

Source: Berry and Cline (1978)

Profit-Wealth Ratios and Weather Variability, by Wealth and Class



ig. 3. Profit–wealth ratios and weather variability, by wealth class. Percentiles: ——, 20th ———, 40th; ---, 60th; ———, 80th.

TABLE 3

DIFFERENCES ON OWNED AND SHARECROPPED LAND OF OWNER-CUM-SHARECROPPERS (N = 352): ESTIMATION OF EQUATION (7)

Variable	Family Male Labor	Family Female Labor	Hired Male Labor	Hired Female Labor	Bullock Pair Labor	Seed	Fertilizer	Other Inputs	Total Output
A	46.6	−2.3	−4.4	−6.6	3.2	51.1	13.2	−39.5	516.0
	(35.6)	(30.0)	(25.3)	(56.8)	(12.1)	(29.3)	(29.7)	(86.2)	(226.2)
B**	20.3	1.2	28.2	15.3	14.2	−.9	−22.5	−13.5	−135.5
	(12.5)	(10.6)	(8.9)	(20.0)	(4.3)	(10.3)	(10.5)	(30.4)	(79.8)
C**	25.7	40.9	2.3	29.0	6.0	6.6	−9.1	12.8	138.9
	(8.5)	(7.2)	(6.0)	(13.6)	(2.9)	(7.0)	(7.1)	(20.6)	(54.0)
D*	10.0	10.7	2.1	16.8	7.1	9.8	−3.3	−4.4	29.6
	(7.7)	(6.5)	(5.5)	(12.4)	(2.6)	(6.4)	(6.5)	(18.7)	(49.2)
E**	10.1	17.7	14.9	25.9	10.8	3.7	18.1	17.3	264.5
	(11.5)	(9.7)	(8.2)	(18.4)	(3.9)	(9.5)	(9.6)	(27.9)	(73.2)
F	17.0	8.1	3.6	23.2	9.9	4.9	−2.2	18.4	143.8
	(13.7)	(11.5)	(9.7)	(21.8)	(4.6)	(11.2)	(11.4)	(33.1)	(86.9)
G**	22.6	43.7	−3.4	−9.5	4.9	−4.5	−10.1	60.4	110.8
	(9.9)	(8.3)	(7.0)	(15.7)	(3.4)	(8.1)	(8.2)	(23.9)	(62.7)
H**	22.5	−.04	−4.3	−23.5	−1.8	28.0	15.1	141.1	83.1
	(12.6)	(10.7)	(9.0)	(20.2)	(4.3)	(10.4)	(10.6)	(30.6)	(80.4)
Irrigated area**[a]	74.7	60.0	43.4	188.0	11.5	49.0	53.0	241.1	851.4
	(13.6)	(11.5)	(9.7)	(21.8)	(4.7)	(11.2)	(11.4)	(33.0)	(86.7)
Plot value**	.81	−.02	−.50	.27	.27	.19	1.2	.56	5.9
	(.33)	(.27)	(.23)	(.52)	(.11)	(.27)	(.27)	(.80)	(2.1)

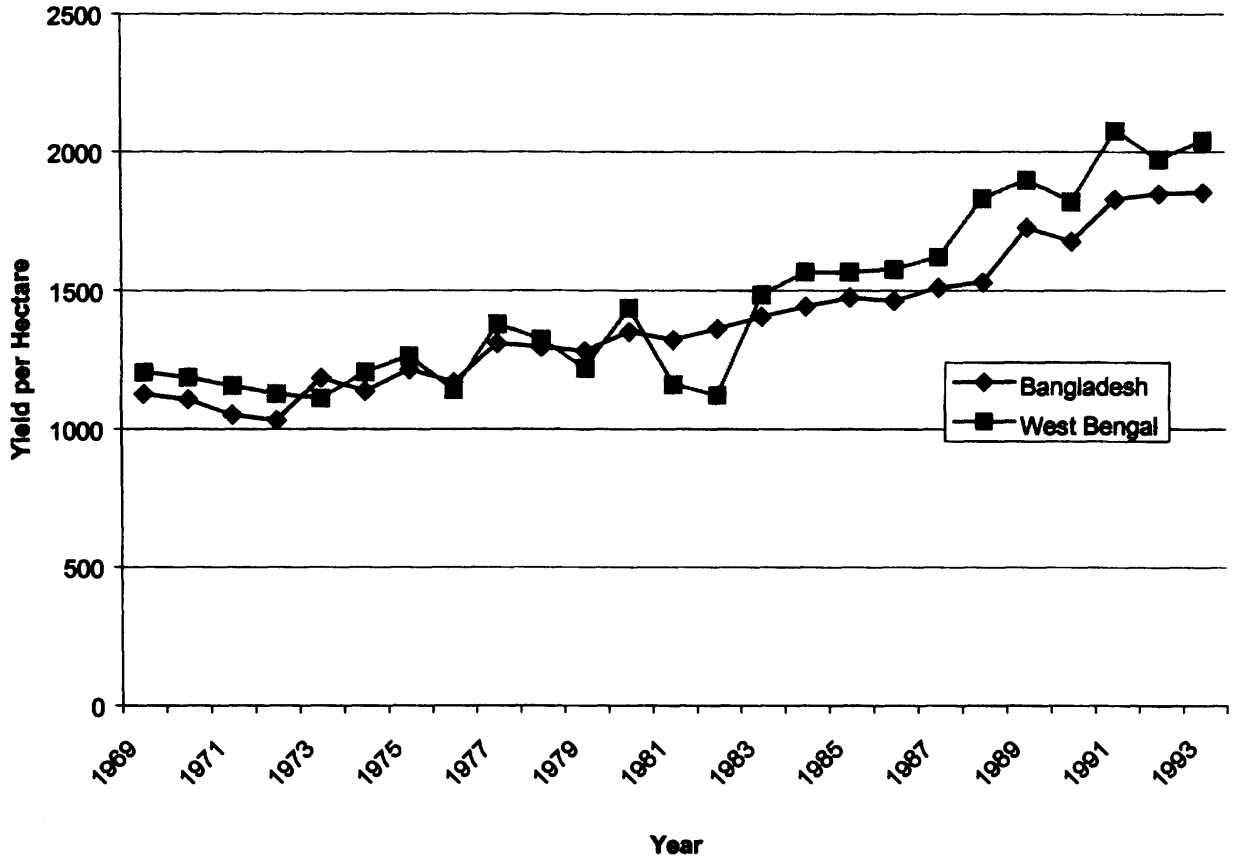

2500
2000
1500
1000
500
0
Yield per Hectare
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Year
Bangladesh
West Bengal

TABLE 5

EFFECT OF REGISTRATION ON THE LOG OF RICE YIELD IN WEST BENGAL, 1979–93

(N=210)

	Model 1 (1)	Model 2 (2)	Model 3 (3)	Model 4 (4)	Model 5 (5)	Model 6 (6)
Sharecropper registration (one year lagged)	.43*** (3.46)	.42*** (3.44)	.43*** (3.55)	.35*** (2.69)	.36*** (2.64)	.36*** (2.63)
Log(rainfall)	...	−.07* (−1.67)	−.08* (−1.82)	−.07 (−1.59)	−.08* (−1.74)	−.08* (−1.77)
Log(public irrigation)	...	.02 (1.01)	.01 (.70)	.01 (.60)	.02 (.83)	.02 (.79)
Log(roads)	...	.28*** (2.75)	.25** (2.46)	.21** (1.99)	.19 (1.55)	.22 (1.54)
HYV share of rice area	...	...	.57*** (2.85)	.45** (2.10)	.47** (2.16)	.47** (2.16)
F-statistic:						
South × year[a]	...	...	...	4.73***	4.36***	4.38***
Left Front × year[b]	...	...	...	...	2.64**	2.65**
Sharecropping × year[c]	...	...	...	...	2.64**	.12
District fixed effects	72.23***	15.10***	8.99***	9.01***	8.47***	7.68***
Year fixed effects	28.31***	27.67***	21.60***	17.63***	17.83***	12.17***
R^2	.91	.92	.92	.92	.92	.92

NOTE.—t-statistics are in parentheses.

TABLE 3

DIFFERENCE-IN-DIFFERENCE MODELS OF LOG OF RICE YIELD (1977–91)

	WHOLE SAMPLE			EXCLUDING DROUGHT YEARS 1981–82		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
West Bengal ×	− .08***	−.07**	− .05	.001	.002	.015
(1979–83)	(−2.43)	(−2.05)	(−1.58)	(.01)	(.06)	(.47)
West Bengal ×	.04	.05	.07**	.04	.04	.06**
(1984–87)	(1.17)	(1.47)	(2.04)	(1.24)	(1.26)	(1.93)
West Bengal ×	.08**	.12***	.18***	.07**	.11***	.17***
(1988–91)	(2.20)	(3.28)	(5.11)	(2.33)	(2.97)	(4.95)
Log(rainfall)	...	.01 (.40)	.007	...	.019	.01
			(.32)		(.70)	(.46)
Log(public	...	.122***	.07***	...	.103	.04***
irrigation)		(7.22)	(4.27)		(5.77)	(2.69)
HYV share of	...	...	1.04***	...	...	1.05***
grain cultivation			(8.18)			(8.21)
area						
District fixed						
effects *F*-statistic	40.02***	20.14***	14.76***	41.43***	18.8***	14.64***
Year fixed						
effects *F*-statistic	20.18***	12.14***	7.73***	21.67***	12.41***	6.04***
R^2	.82	.85	.87	.83	.85	.88
Sample size	424	424	424	367	367	367

NOTE.—*t*-statistics are in parentheses.

** Significant at the 5 percent level.

*** Significant at the 1 percent level.

Table IV: Household Labor Supply

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Weekly Hours in Labor Force									**Work Location**	
	Total Household Hours	Total Household Hours	Total Household Hours	Total Household Hours	Total Household Hours	Hours per Member Aged 5-69	Hours per Member Aged 5-69	Total Household Hours	Total Household Hours	Residence Used for Economic Activity	Household member commutes more than 2 hours
Squatter	-7.65	-8.05	-33.35	-6.79	-7.33	-1.53	-1.64	-4.67	-4.7001	0.02	-0.03
	[4.41]+	[4.40]+	[17.58]+	[4.65]	[4.64]	[1.11]	[1.11]	[4.58]	[4.57]	[0.03]	[0.01]*
Squatter*program	13.50	-7.96	58.55	12.34	-12.59	3.04	-2.06	13.39	-10.91	-0.11	0.04
	[6.63]*	[11.70]	[25.49]*	[7.48]	[12.44]	[1.98]	[3.35]	[7.37]+	[14.33]	[0.05]*	[0.02]*
Squatter*program periods		10.10	8.16		11.78		2.41		10.10		
		[4.27]*	[4.17]+		[4.60]*		[1.14]*		[5.11]*		
Squatter*program* tenure			-0.95								
			[0.53]+								
Squatter*program* working-age members			-28.05								
			[11.44]*								
(Squatter*program* working-age members)^2			3.50								
			[1.25]**								
Fixed effects:	*City*	*City*	*City*	*City*	*City*	*City*	*City*	*Neighbor-hood*	*Neighbor-hood*	*City*	*City*
Full demographic controls?	*Yes*	*Yes*	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*
Implied program effect: N=4, T=15, P=2	*13.50*	*12.24*	*4.35*	*12.34*	*10.96*	*3.04*	*2.76*	*13.39*	*9.29*	*-0.11*	*0.045*
	[6.63]	*[6.77]*	*[8.19]*	*[7.48]*	*[7.53]*	*[1.98]*	*[2.00]*	*[7.37]*	*[7.65]*	*[0.05]**	*[0.02]**
Implied program effect: N=3, T=15			*7.89*								
			(7.09)								
Implied program effect: N=3, T=10			*12.66*								
			(8.19)								
Observations	*2465*	*2465*	*2465*	*2489*	*2489*	*2489*	*2489*	*2489*	*2489*	*2489*	*2489*

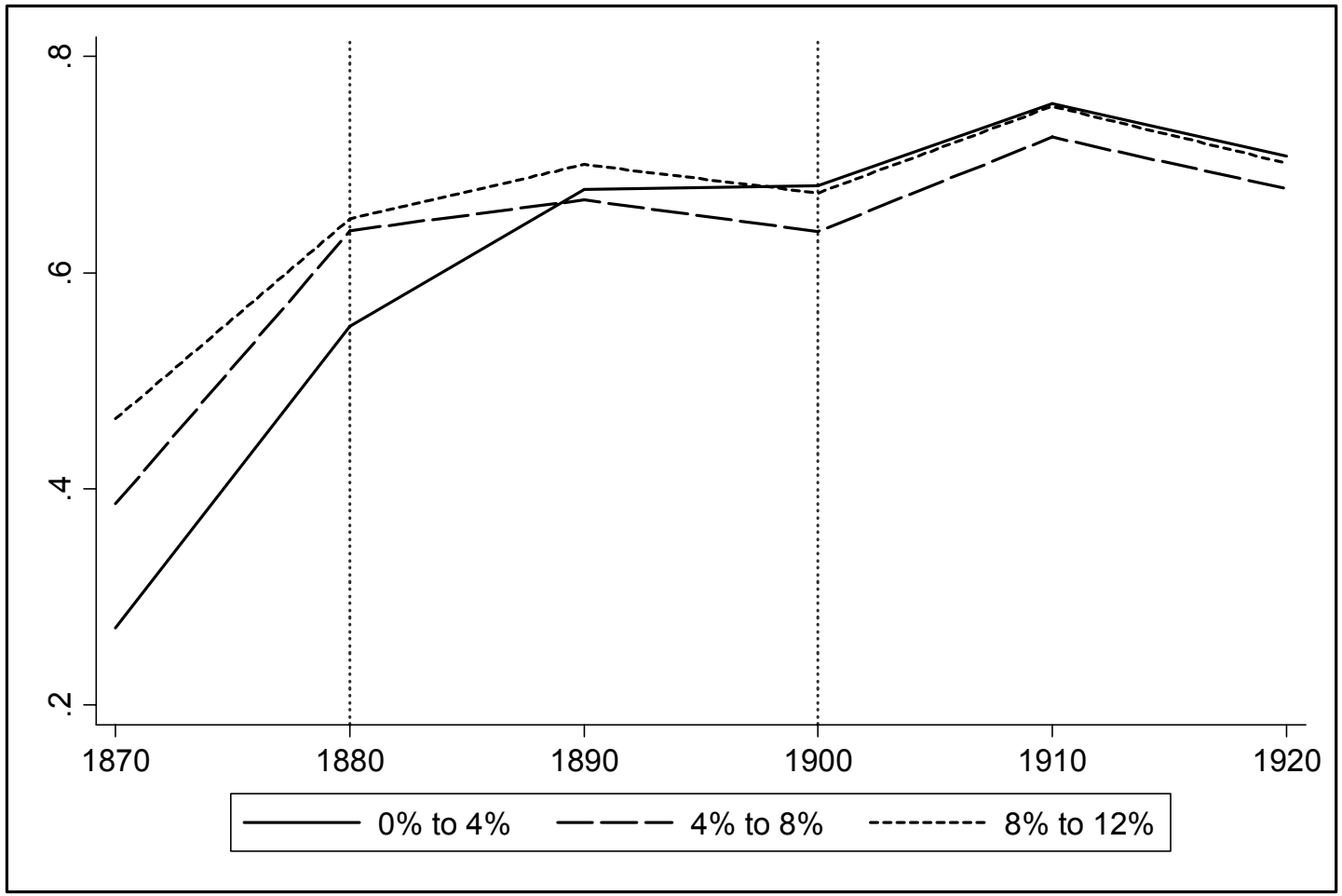
	Uninstrumented (1)	Instrumented (2)	Rights with Approval (3)	Rights without Approval (4)
Rights with approval	.03	.12		
	(1.93)	(1.93)		
Rights without approval	.02	.11		
	(1.56)	(1.68)		
Number of past tree plantings	.19	.14		
	(4.34)	(2.72)		
Average age	−.00	−.00	−.01	−.00
	(.40)	(.04)	(.26)	(.52)
Value of durables	.00	.00	−.00	−.00
	(1.80)	(2.21)	(.49)	(1.98)
Livestock value	−.00	−.00	−.00	.00
	(2.05)	(1.78)	(2.48)	(2.77)
Formal education of head	.01	−.01	.18	.00
	(.23)	(.47)	(1.68)	(.04)
Women	−.01	−.01	−.08	.04
	(.78)	(.21)	(2.66)	(1.58)
Men	.01	.02	−.02	.03
	(2.03)	(2.28)	(1.67)	(1.32)
Rooms	−.00	−.01	.08	−.03
	(.45)	(1.22)	(3.93)	(1.34)
Distance from house	.01	.01	−.05	.01
	(1.44)	(1.63)	(1.39)	(.35)

TABLE 4

WASSA: INVESTMENTS IN TREE PLANTING (with Household Dummy Variables)
(N = 1,074)

	Uninstrumented (1)	Instrumented (2)	Rights with Approval (3)	Rights without Approval (4)
Rights with approval	.07	.11		
	(1.77)	(1.02)		
Rights without approval	.05	.28		
	(.86)	(1.94)		
Number of past tree plantings	.22	.19		
	(3.52)	(2.85)		
Soil very fertile	.08	.05	.58	−.10
	(.70)	(.42)	(4.38)	(1.29)
Soil fertile	.05	.03	.26	−.07
	(.49)	(.32)	(2.16)	(1.01)
Distance from house	.00	.01	−.06	−.02
	(.19)	(.58)	(3.64)	(1.78)
Field area	−.03	−.03	.00	−.00
	(12.78)	(12.78)	(1.04)	(.24)

Figure 3. Acres of Improved Land (per farm acre), by County Woodland Group and Decade



Notes: For counties in these three woodland groups, this figure displays the average number of improved acres of land per acre of farmland in each time period. The two vertical dotted lines represent the approximate date of barbed wire's introduction to farmers (1880) and barbed wire's universal adoption by farmers (1900).

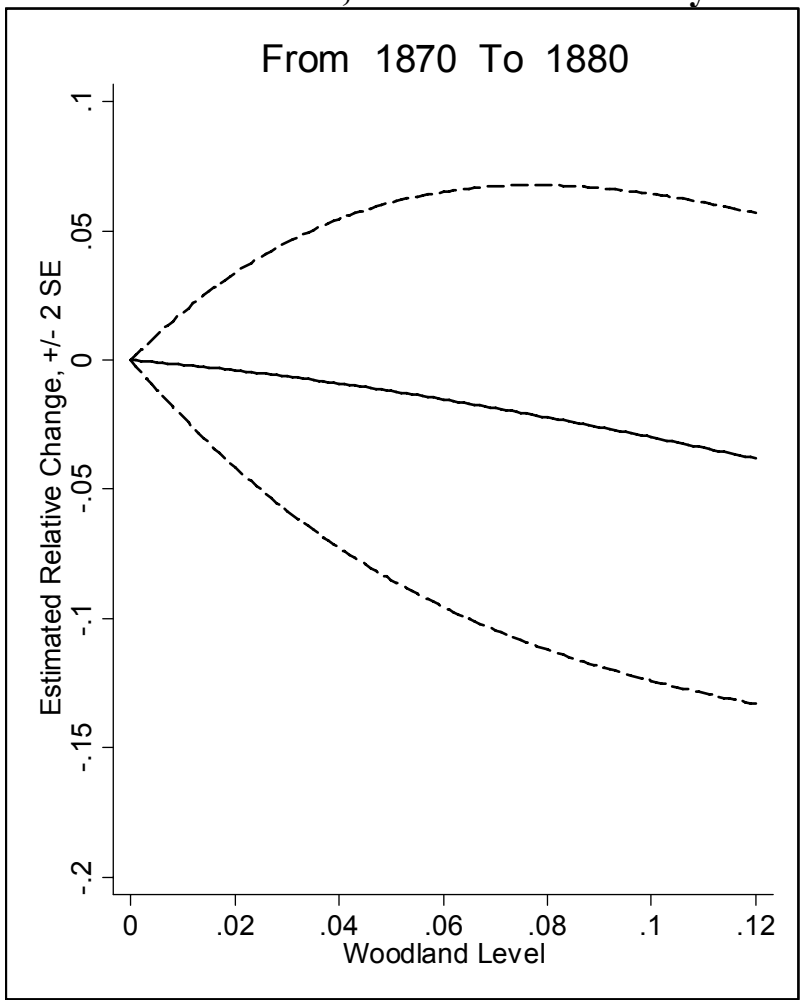
$$Y_{ct} - Y_{c(t-1)} = \alpha_{st} + \sum_{t=2}^{T}(\beta_{1t}W_c + \beta_{2t}W_c^2 + \beta_{3t}W_c^3 + \beta_{4t}W_c^4) + \epsilon_{ct}.$$

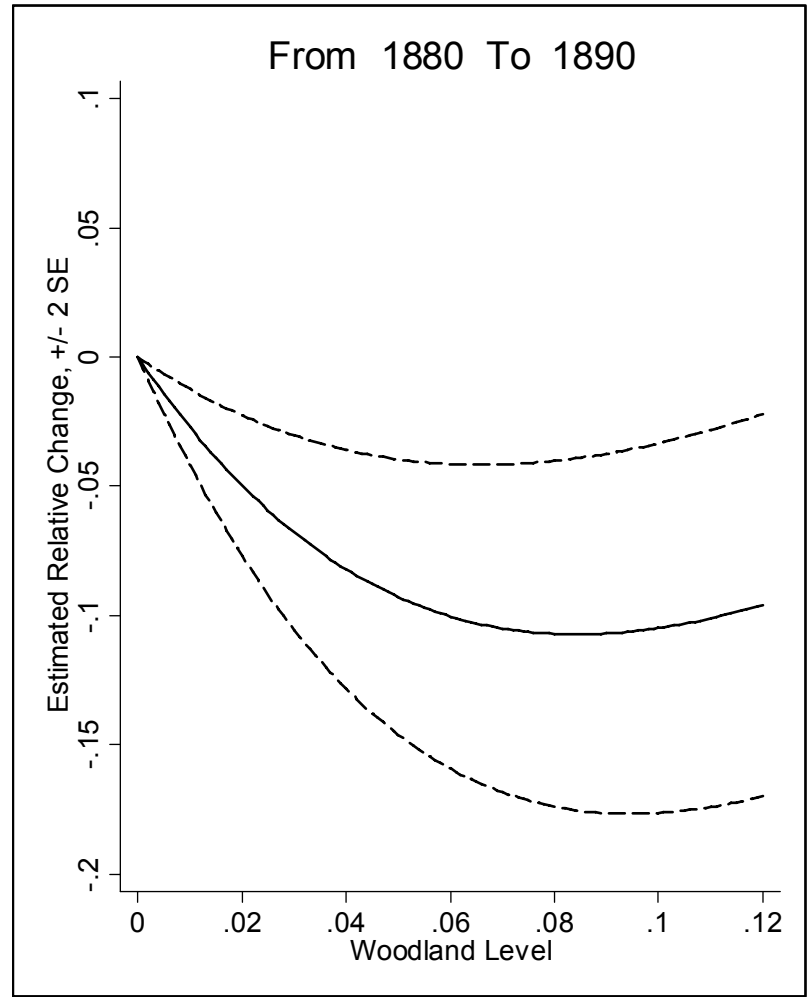
▸ illustration

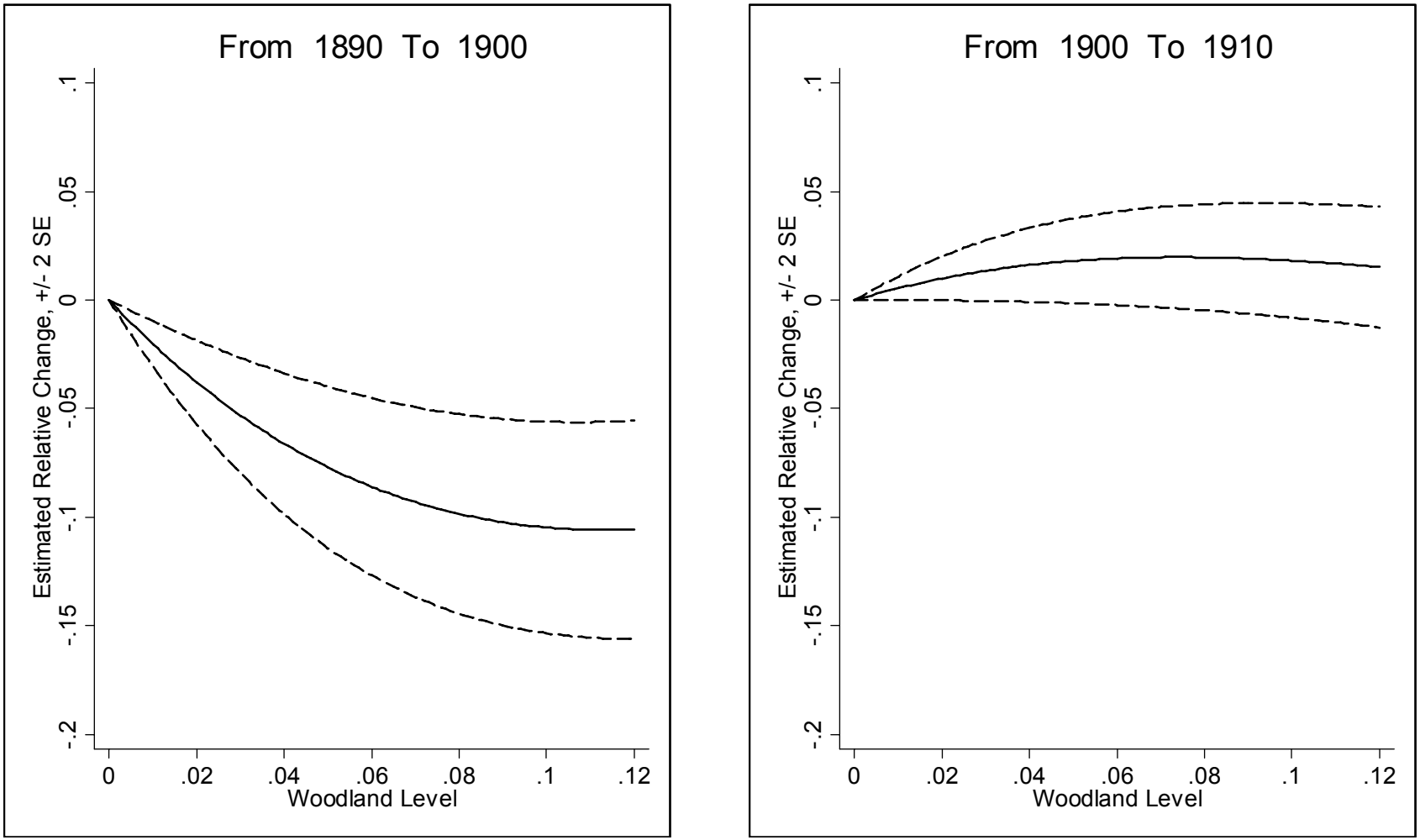
Table 3. Estimated Changes in the Improvement Intensity of Farmland and Settlement, Evaluated at Representative Woodland Levels

	Woodland:	Acres of Improved Land, per acre in farms		Acres of Land in Farms, per county acre	
		0% vs. 6% (1)	6% vs. 12% (2)	0% vs. 6% (3)	6% vs. 12% (4)
	Decade:				
Before Barbed Wire	1870 - 1880	0.015 (0.040) [0.22]	0.023 (0.013)	0.039 (0.026) [0.41]	0.028** (0.010)
After Barbed Wire's Introduction	1880 - 1890	0.100** (0.030) [4.12]	– 0.004 (0.012)	0.129** (0.023) [3.81]	0.048** (0.009)
	1890 - 1900	0.086** (0.020) [3.40]	0.020* (0.009)	0.128** (0.026) [3.13]	0.057** (0.009)
After Barbed Wire's Universal Adoption	1900 - 1910	– 0.019 (0.011) [2.25]	0.004 (0.006)	– 0.022 (0.024) [0.36]	– 0.014 (0.009)
	1910 - 1920	0.003 (0.010) [0.31]	0.006 (0.004)	0.024 (0.016) [1.59]	– 0.003 (0.007)
	R^2	0.4432		0.5012	
	Observations	1885		1885	

Figure 4. Estimated Changes in the Improvement Intensity of Farmland, +/- 2 Standard Errors, Relative to a County with 0% Woodland







Notes: From estimating equation 8 for the acres of improved land per acre of farmland, these figures report the change in a county with each woodland level relative to the change for a county with 0% woodland, plus or minus 2 standard errors.

Table 5. Estimated Changes in Crop Productivity and Crop Intensity

		All Crops				At-Risk Crops			
		Productivity		Acres of Cropland, per acre in farms		Productivity		Acres of At-Risk Crops, per acre of cropland	
	Woodland:	0% vs. 6%	6% vs. 12%	0% vs. 6%	6% vs. 12%	0% vs. 6%	6% vs. 12%	0% vs. 6%	6% vs. 12%
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Decade:								
After Barbed Wire's Introduction	1880 - 1890	0.234**	0.018	0.121**	0.015**	0.292**	0.036	0.058*	0.000
		(0.057)	(0.025)	(0.015)	(0.005)	(0.067)	(0.027)	(0.023)	(0.007)
		[3.31]		[8.01]		[3.47]		[2.84]	
	1890 - 1900	– 0.046	– 0.003	– 0.013	– 0.011**	– 0.057	– 0.012	0.007	– 0.005
		(0.039)	(0.018)	(0.009)	(0.004)	(0.046)	(0.021)	(0.015)	(0.006)
		[0.97]		[0.24]		[0.86]		[0.91]	
After Barbed Wire's Universal Adoption	1900 - 1910	0.054	– 0.019	0.039**	0.004	0.058	– 0.027	0.020	– 0.015
		(0.035)	(0.018)	(0.010)	(0.004)	(0.039)	(0.019)	(0.019)	(0.009)
		[1.70]		[3.44]		[1.81]		[1.75]	
	1910 - 1920	– 0.036	0.014	0.010	0.001	0.011	0.038	0.016	0.005
		(0.042)	(0.025)	(0.007)	(0.004)	(0.049)	(0.029)	(0.015)	(0.009)
		[0.95]		[1.06]		[0.44]		[0.63]	
	R^2	0.3949		0.3922		0.4000		0.2777	
	Observations	9104		1960		7320		1960	

Table 2: Housing Investment and Property Titling[+]

	Number of annual additions or renovations[++]			Any renovation within 2-year period[+++]			Any addition within 2-year period		
Universe:	*Beneficiaries in program areas* (1a)	*Program areas only* (1b)	*Beneficiaries only* (1c)	*Beneficiaries in program areas* (2a)	*Program areas only* (2b)	*Beneficiaries only* (2c)	*Beneficiaries in program areas* (3a)	*Program areas only* (3b)	*Beneficiaries only* (3c)
After_program	0.275 (0.075)**	0.093 (0.040)*	0.083 (0.079)	0.126 (0.033)**	0.036 (0.021)	0.047 (0.043)	0.020 (0.008)**	0.031 (0.007)**	0.003 (0.008)
Beneficiary		-0.108 (0.040)**			-0.060 (0.021)**			-0.010 (0.010)	
Beneficiary* After_program		0.182 (0.078)*			0.089 (0.042)*			0.007 (0.015)	
Program_area			0.021 (0.059)			0.009 (0.038)			-0.007 (0.009)
Program_area* After_program			0.192 (0.095)*			0.080 (0.037)*			0.018 (0.017)
Household-period obs	*800*	*3180*	*1306*	*794*	*3166*	*1300*	*756*	*3026*	*1300*

Table 4: Investment Demand and Property Titling[+]

	Any credit desired?[++]	Any desired addition or renovation since moving in?[+++]	Credit requested for housing improvements[++++]	Credit received for housing improvements
	(1)	(2)	(3)	(4)
	(N=756)	*(N=800)*	*(N=1271)*	*(N=1271)*
Program_neighborhood	0.069	0.042	36.9	-57.8
	(0.032)*	(0.020)*	(158.2)	(230.2)
After_program			-43.1	-32.5
			(168.40)	(286.50)
Program_neighborhood* (After_program)			431.9	229.8
			(185.9)*	(282.21)