Land-use policies and corporate investments in agriculture in the Gran Chaco and Chiquitano

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Growing demand for agricultural commodities is causing the expansion of agricultural frontiers onto native vegetation worldwide. Agribusiness companies linking these frontiers to distant spaces of consumption through global commodity chains increasingly make zero-deforestation pledges. However, production and land conversion are often carried out by less-visible local and regional actors that are mobile and responsive to new agricultural expansion opportunities and legal constraints on land use. With more stringent deforestation regulations in some countries, we ask whether their movements are determined partly by differences in land-use policies, resulting in "deforestation havens." We analyze the determinants of investment decisions by agricultural companies in the Gran Chaco and Chiquitano, a region that has become the new deforestation "hot spot" in South America. We test whether companies seek out less-regulated forest areas for new agricultural investments. Based on interviews with 82 companies totaling 2.5 Mha of properties, we show that, in addition to proximity to current investments and the availability of cheap forestland, lower deforestation regulations attract investments by companies that tend to clear more forest, mostly cattle ranching operations, and that lower enforcement attracts all companies. Avoiding deforestation leakage requires harmonizing deforestation regulations across regions and commodities and promoting sustainable intensification in cattle ranching.

pollution haven | leakage | land-use change | soy | cattle

A growing population and changes in consumption patterns worldwide are driving an increasing demand for agricultural commodities, particularly meat, vegetable oils, and sugar. These commodities are brought to consumers through complex chains of actors, called global commodity chains (1). At the other end of those chains are producers, often in places far removed from consumers, who respond to increasing demand by intensifying agriculture, switching crops, and expanding cropland into natural ecosystems. Depending on the amount of additional production coming from yield vs. area increases, it is projected that 81–147 million more hectares of agricultural land will be needed to meet global demand for food by 2030 compared with 2000 (2). As the world's appetite for land increases, there is a growing recognition that the supply of land for future agricultural expansion is limited, and that the conversion of remaining land reserves, most of which are in tropical regions, comes with important tradeoffs—such as biodiversity loss or climate regulation (3–5). It is therefore necessary to seek ways to meet the demand for food without clearing natural ecosystems.

Traditionally, the protection of natural ecosystems has been achieved through public parks and private forest reserves. The recent recognition of the role of global commodity trade in forest conversion has led to a new emphasis on the private governance of flows of goods, via production and sustainability standards (6). Successful land-use governance requires a mix of flow- and territory-based private and public policy instruments delivered by both state and private actors (7). For example, the recent reduction in deforestation in the Brazilian Amazon has been attributed to a combination of enforcement of laws, interventions in soy and beef supply chains, restrictions on access to credit, expansion of protected areas, and a decline in demand for new deforestation (8, 9).

A key challenge to environmental conservation in commodity frontiers (i.e., frontiers of expansion of agricultural commodities into natural ecosystems) concerns the indirect effects of policy interventions that are restricted to a single territory or commodity. The reduction of deforestation in the Brazilian Amazon may have been achieved at the cost of higher rates of deforestation in the Cerrado, another valuable Brazilian biome (10). Elsewhere, countries experiencing a transition from net deforestation to net reforestation (i.e., a forest transition) due to strict land-use policies could do so in part because they increased their imports of wood products from laxer neighbors (11, 12). Because commodities such as soybeans, beef, or timber are largely substitutable, any intervention limiting their expansion in one place may displace it to another, assuming an inelastic demand. This leakage—defined as a displacement of an environmental impact due to a policy intervention (13)—can be the result of an outbound movement of actors facing diminishing agricultural rents due to that intervention. It can also result from an increase in agricultural rents elsewhere due to a supply scarcity created by the intervention, which incentivizes investments outside the intervention area.

Existing assessments of land-use-related leakage are not sufficiently robust to support policies (14, 15). Most studies also do not uncover how environmental regulations affect decision making by economic actors. The focus so far has been on how new environmental regulations push economic actors to relocate elsewhere rather than on the attractiveness of weak regulatory environments. This study aims to better understand how investment choices by

Significance

A growing global demand for agricultural products such as soybeans and beef is causing agriculture to expand into forest ecosystems. Many countries are tightening environmental regulations as a response. Because agricultural companies can move, there is a risk that stringent land-use regulations might just displace land conversion geographically. A better understanding of how these regulations affect companies' movements is therefore crucial for designing effective conservation policies. Here we analyze the determinants of siting choices by agricultural companies. We find that companies that tend to clear more forest prefer areas with lower deforestation restrictions, and that all companies prefer areas with low enforcement. However, these effects are less important than the availability of forestland or the proximity to current investments.

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Data deposition: The database used for the model, as well as the STATA code, the questionnaires, and some additional tables (see *Supporting Information*) are available to the readers under the following permanent link: https://purl.stanford.edu/yn536gj2686.

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agricultural companies are influenced by deforestation regulations in the investment destination, using the case of deforestation frontiers in the Gran Chaco and Chiquitano woodlands.

The idea that companies move to avoid environmental regulations is known as the "pollution haven hypothesis" (PHH). It states that, as barriers to trade and foreign investments are removed, companies will relocate polluting activities to countries with weaker environmental regulations, all else equal. Early studies estimating the effect of exogenous environmental regulations found little or no evidence supporting the PHH (16, 17). More recent models accounting for the endogeneity of environmental policies did find a significant and robust effect (18, 19). Tests of the PHH for commercial agriculture in developed economies found that polluting activities, such as large-scale livestock operations, tend to locate in weaker jurisdictions (20–22). Not all companies respond equally to environmental regulations: Companies that pollute more have a greater tendency than others to site where environmental regulations are weak (23). Countries may engage in "regulatory competition," in which they modify their environmental regulations in function of their competitors' regulations, potentially fueling a "race to the bottom" (24). Evidence shows that such regulatory competition can increase or decrease regulations (24, 25).

The concept of pollution havens relies on the mobility of economic actors and capital, as facilitated by trade liberalization, and on the existence of significant regulatory differences between states or regions (26). Transnational agribusiness corporations are highly dynamic and responsive to market changes. Given their visibility and high levels of concentration, they are regular targets of environmental activists' campaigns for their role in tropical deforestation. Often, these companies are not involved in production themselves and are therefore not direct agents of deforestation: They source their primary material from local producers who clear the land.

Agricultural frontiers in tropical forests have long been dominated by smallholders. The risk of leakage from conservation interventions in such frontiers is limited due to a weak integration with global markets and constrained mobility by undercapitalized households. By contrast, many recent commodity frontiers are linked with global supply chains and dominated by large-scale agricultural operations (27, 28). Although the majority of these companies are local or regional, many have become active internationally and are highly mobile (29, 30), as exemplified by the global land rush following the 2008 financial crisis (31). These companies are expected to be very responsive to geographic differences in the conditions of production, including environmental regulations.

In the soybean and cattle frontiers of South America, differences in environmental regulations increased dramatically in the 2000s. The Brazilian Amazon, a biome both iconic and under threat for several decades, became the focus of conservation efforts. Land use in other biomes, such as the Cerrado in Brazil, the Chiquitano in Brazil and Bolivia, and the Gran Chaco in Argentina, Bolivia, and Paraguay, remained largely unregulated until the mid-2000s. Decentralized land-use zoning policies have recently created large regulatory differences, particularly for the countries and provinces of the Gran Chaco and Chiquitano. ("Provinces" are equivalent to states; the word refers to provinces in Argentina and departments in Bolivia and Paraguay.) This allows for a natural experiment to investigate the influence of land-use regulations on corporate investments in agricultural frontiers.

This study focuses on new investments in land between 1990 and 2012 by medium- to large-scale soy and cattle producers on deforestation frontiers in the Gran Chaco and Chiquitano. Using original empirical data, we ask how strong the effect of deforestation regulations is relative to other factors in determining the location of those investments, and whether differences in these regulations lead to a "deforestation haven" effect.

Background

The dry woodlands of the Gran Chaco and Chiquitano are one of the largest remaining continuous extents of native vegetation in South America, covering over 700,000 km^2 of Argentina, Bolivia, and Paraguay (counting only forested areas) (Fig. 1). Over the last two decades, these woodlands have experienced some of the world's highest rates of conversion to agriculture, primarily for soybean farming and cattle ranching (32–35). The rise of soybean farming since the late 1970s can be attributed to increasing global demand, improved agricultural technologies (particularly genetically modified seeds and no-till agriculture, introduced in the 1990s), and an increase in rainfall that improved the region's suitability for agriculture (33, 36). Cattle ranching was pushed further into the frontier by croplands (37), also benefiting from favorable economic conditions in some periods (38). Many companies are active in both the soy and cattle sectors, and in several countries (30).

Early forest regulations in the region (laws 13.273 in Argentina, 1.700 in Bolivia, and 422 in Paraguay) included basic provisions for soil conservation (windbreaks and limits to agriculture on steep terrain) and forest reserves (a percentage of properties to be set aside). These varied between provinces and over time: Some provinces imposed high forest reserve requirements since the 1980s, whereas others did not impose any until the mid-2000s. Apart from this, protected areas were the main legal instrument for conservation until the 2000s. The rapid deforestation associated with agricultural expansion in the early 2000s was met by increasing protests from environmental groups, leading to temporary moratoria on forest clearing in some Argentine provinces, and a zero-deforestation law for the Atlantic forest of Paraguay (law 2524; a proposition to extend it to the Chaco was rejected). In Argentina, continued pressure by civil society led to the adoption in 2007 of a law (26.331) that required each province to design a zoning plan that imposed higher percentages of forest reserves on private properties, increased the forestland area under strict protection, and raised sanctions for illegal clearing. Sanctions remained low throughout the study period in Bolivia and Paraguay. Governments and nongovernmental organizations (NGOs) started satellite-based deforestation monitoring in the 2000s, but effective monitoring and enforcement remained a challenge, made worse by high levels of corruption (*Supporting Information*).

Disparities in land-use regulations may translate into differences in the expected rent of production, affecting siting choices for companies investing in commodity agriculture. The choice to acquire land in a new place is determined by push and pull factors. Push factors determine the decision to invest outside the place where the company already has investments. They include limits to expansion at home due to restrictions on deforestation, decreasing profits, increasing risks, or a desire to diversify investments. Pull factors explain why a company invests in a particular place within the set of potential destinations, given its decision to move.

A company wanting to invest in land can be assumed to choose a site that maximizes the expected value of future production, given the information available to it. That value is a function of fixed costs, running costs, returns, and risks. Fixed costs include land purchase and development and the cost of setting up infrastructure in a new area. Running costs include input costs (e.g., labor and transportation costs) and transaction costs (e.g., administrative costs). Returns are a function of yields and producer prices, which are in turn influenced by export taxes and exchange rates. Risk may be biophysical (e.g., droughts), economic (e.g., inflation), political (e.g., tenure insecurity), or physical (e.g., guerilla).

Deforestation regulations reduce the quantity of land available for agricultural expansion, potentially raising land prices. Higher percentages of on-property legal reserves also increase the average cost of production. Stricter deforestation regulations may increase the transaction costs associated with legal deforestation through administrative costs (e.g., environmental impact assessments) and through the opportunity costs associated with delays in the authorization procedures. Higher enforcement also makes illegal deforestation costlier, and riskier. Changes in deforestation regulations may increase perceived risk, to the extent that further changes are anticipated that might compromise the company's activities.

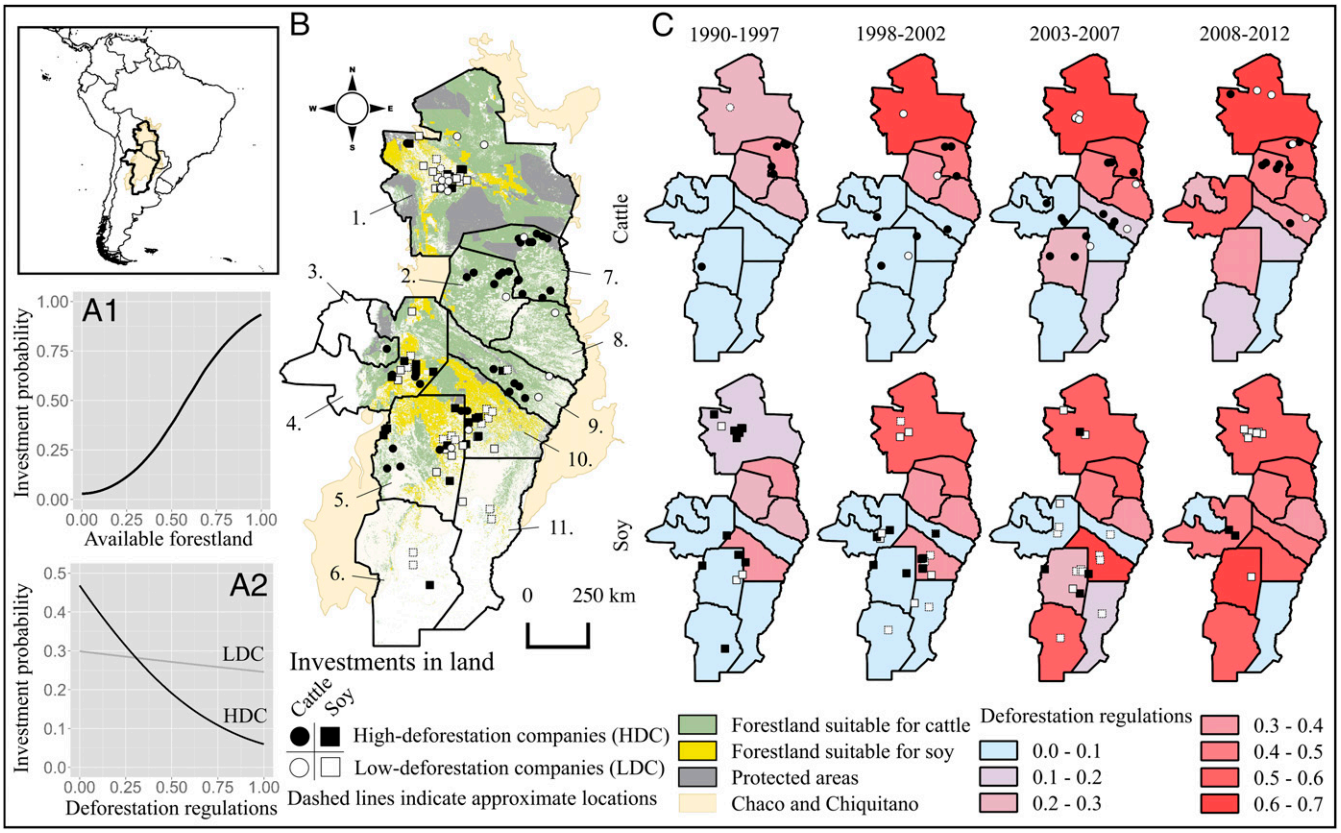

Fig. 1. (*A1* and *A2*) Marginal probabilities of investment for Santa Cruz de la Sierra; high/low-deforestation companies are companies with a propensity to acquire forested land higher/lower than the sample median (0.91). (*B*) The provinces are 1, Santa Cruz de la Sierra; 2, Boquerón; 3, Jujuy; 4, Salta; 5, Santiago del Estero; 6, Córdoba; 7, Alto Paraguay; 8, Presidente Hayes; 9, Formosa; 10, Chaco; 11, Santa Fe. (*C*) Location of investments and stringency of deforestation regulations by province and time period. Additional details in *Supporting Information*.

To analyze the siting choices of soy and cattle companies (pull factors), we use semistructured interviews with 82 soybean and cattle companies in Argentina, Bolivia, and Paraguay, totaling 2.5 Mha of properties in the Gran Chaco and Chiquitano. We also use key informant interviews and secondary data from state, nonstate, and local research institutions. Multivariate statistical models estimate whether the choice by companies to invest in land in particular provinces in the region is explained by the stringency of deforestation regulations in these provinces, controlling for other factors. We do not analyze the role of push factors, because it would have required a sample of nonmovers comparable to the movers, matching moving companies with similar nonmovers from each region of origin, which are numerous and widely distributed geographically. We compare the results of our spatial statistical analysis with the attributes that interviewed producers associate most frequently with investment destinations.

Results and Discussion

As a result of globalization, ties between agricultural producers and their land are becoming looser. Many of today's large-scale producers in the Chaco and Chiquitano are highly educated, live in cities, travel internationally, and keep track of politics, taxes, and the Chicago mercantile exchange. Most of them manage production remotely, and some, empowered by the soy boom, own large transnational companies that, after expanding into neighboring provinces and countries, are looking toward Angola or Mozambique (4).

The companies in our sample invested primarily in Santa Cruz, Bolivia (31 out of 118 investments; of 82 companies, 18 invested in two or more provinces), followed by Santiago del Estero (21), Chaco (15), and Salta (14) in Argentina (Fig. 1*B*). Of the 2.5 Mha of forest, pasture, and cropland owned by these companies in the study area, 97% were in another province than the province of origin of the company, and 50% were in another country (Table S1; additional descriptive statistics are provided in *Supporting Information*). In our nested logit models, the variables that best explain the probability of companies choosing a particular destination for new investments in land during specific time periods are distance to current investments and available forestland (Table 1 and Fig. 1*A1*). The coefficient for deforestation regulations was not significant on its own but became significant and negative when included in interaction with the company propensity to acquire forested land (defined as the percentage of properties acquired by the company that were forested at the time of acquisition; Fig. 1*A2*). The coefficient for enforcement was significant and negative. The coefficient for producer prices was significant and positive only in the models without enforcement. These results were consistent in models with a lagged regulation variable (Table S2).

We coded a total of 610 associations between investment destinations and attributes in the interviews (i.e., instances of production-related characteristics mentioned in reference to these destinations). Attributes corresponding to the variables included in the statistical models (e.g., land prices) together represented 51% of associations (Table S3). The attributes most frequently associated with investment destinations were those related to yields and land prices (19 and 12%). Deforestation regulations represented 5% of all associations in the interviews, and enforcement 1%. Companies mentioning regulations and enforcement also had a higher propensity to acquire forestland than others (90% vs. 66%, Welch *t* test *P* value 0.001). Attributes not accounted for in the models were, among others, juridical insecurity (7%), climatic risk (4%), opportunities (3%), and the scarcity of labor and service providers (3% each) (Table S4). The main insights from these results are as follows.

Table 1. Nested logit models of the probability of investment

Variable	(I)	(II)	(III)
Proximity to current investments	4.075***	4.274***	4.476***
Transport costs, $/km	4.241	2.649	4.434
Producer prices, $	3.659**	3.276*	0.994
Yields, tons/ha	2.527	3.635	2.034
Land prices, $1,000/ha	0.199	0.273	0.433
Available agricultural land	5.403	6.729*	4.589
Available forestland	5.812**	7.156**	6.186**
Deforestation regulations (DR)	−2.013	0.312	2.126
DR*propensity to acquire forestland		−5.317**	−5.831**
Enforcement			−22.25**

Dissimilarity parameters and other metrics are provided in *Supporting Information*. ***$P < 0.01$, **$P < 0.05$, *$P < 0.1$.

Companies Invest Close to Their Current Investments. If they find good conditions nearby, producers have few incentives to move far away because distance imposes management and transaction costs. Investing in a neighboring province makes the commute from a central office easier for managers and allows for economies of scale by using the same transportation and processing infrastructure (39). Nearby places are more likely to be similar to the places that the producers know, making adaptation easier. Companies are also more likely to gain direct access to good information on investment conditions through social networks.

Companies Invest Where There Is Abundant Forestland. Investments are generally directed toward forested areas rather than toward areas where agriculture is already consolidated. The properties acquired in our sample had an average 68% of remaining forest cover at the time of acquisition. Forestland was on average $1,157 cheaper per hectare than agricultural land for the same province and year (paired t test P value of 0.01). Large properties tend to be more available in forested areas than in established agricultural regions, where the land market is less dynamic. In areas with a long history of agriculture, some soils have been degraded by inappropriate agricultural practices, so that recently cleared land may be more productive (40).

Companies That Clear More Forest Invest Where Deforestation Regulations Are Weak, and All Companies Seek Out Areas with Low Enforcement. Even where forestland is physically abundant, regulations may limit the ability of firms to put that land into production. To assess the impact of regulations and their enforcement in altering investment behavior, we use our statistical model to run a counterfactual simulation in which there were no increases in Argentinean deforestation regulations and enforcement during the second half of the 2000s (*SI Background* and *SI Materials and Methods*). This simulation indicates that 7.7% of all land investments, corresponding to about 170,000 ha of forestland based on sample averages, would have happened in the Chaco region of Argentina instead of Bolivia and Paraguay. This effect is significant but relatively limited as it corresponds to the greatest change in regulations that recently occurred in the region. In addition, the effect is heterogeneous among actors. The simulated changes in investment behavior are driven primarily by the companies that tend to acquire forestland and are thus more reliant on deforestation.

Companies Invest Where Land Has a High Agroecological Potential and Is Cheap. Yields and land prices were cited the most frequently in the interviews as determinants for siting choices. These variables were probably measured at too coarse a resolution to be significant in the statistical models. Yields vary widely within provinces, depending on soil and climate conditions. The land price variable aggregates marginal forestland with productive agricultural land and does not accurately represent the spatial and temporal heterogeneity of actual land prices. A similar argument can be made for transport costs, although attributes related to this variable were not frequently associated with investment destinations in the interviews. Recent research suggests that transport costs are less important than yields for location decisions (41, 42). A model of the determinant of land prices, including the effect of deforestation regulations, is discussed in *Supporting Information*, as are the effects of producer prices and juridical security. Table S5 summarizes the role of qualitative and quantitative evidence in each of the above findings.

Deforestation Havens in the Chaco? Our results suggest that agricultural companies' siting decisions are primarily a function of proximity to current investments and availability of forestland, rather than of deforestation regulations. However, the effect of these regulations and their enforcement is significant, especially considering that the analysis is limited to a region of relatively low regulations and enforcement. Had we included biomes with more stringent deforestation regulations, such as the Brazilian Amazon or the Atlantic Forest in Paraguay, we might have found a stronger effect. In the interviews, although not among the most frequently cited siting factors, deforestation regulations were considered a deterrent for investments. Increased regulations may also motivate additional movements away from the more regulated areas (push effect) that are not captured here.

The importance of the propensity to acquire forestland reflects a differentiation of companies' strategies. Whereas some companies tend to produce in consolidated agricultural areas, relying on efficient agricultural systems based on outsourced services (43), others specialize in the colonization of forested areas, where they capture the transitory profits associated with resource frontiers (28). These deforestation-intensive companies, like "polluting" companies in the industrial sector (23), are more sensitive to environmental regulations because their profitability depends on the integration of cheaper, forested land. They are usually involved in cattle ranching: Companies in our sample that focused exclusively on crops were less likely to acquire forestland (Fig. S1). The association of deforestation bias with cattle ranching may be explained by the greater mobility of ranching operations, which do not require great proximity to infrastructure. Their profitability is also more often based on the incorporation of cheap land and on the high soil fertility just after clearing (42). Farming companies are more dependent on input and services and seek proximity to agricultural clusters (39). More farmers than ranchers in our sample were also active at other levels of the supply chain, such as storage, services, or trade (*Supporting Information*). The fact that all companies preferred to invest in places with lower enforcement, may reflect a general aversion to transaction costs. Even companies with a lower deforestation bias that do not seek out lower regulations often acquire properties with some amount of forestland left on them and may see strict enforcement of deforestation regulations (e.g., deforestation permits) as an obstacle to business. The enforcement index may also pick up other, unmeasured aspects of transaction costs.

Our results thus support the PHH in the context of agricultural frontiers but show that the "deforestation haven" effect is a

relatively minor one that applies primarily to deforestation-intensive companies, often cattle ranchers. This finding also suggests that deforestation regulations are somewhat successful at diminishing incentives for forest clearing. Note that our sample may be biased toward large, well-connected, and relatively law-abiding companies, because these are more likely to be referred to for interviews. We might therefore be missing a shift of the deforestation toward less compliant actors, and actors that are more mobile due to their lesser involvement in local supply chains.

Governing the Frontier. Governments fearful that increasing deforestation regulations might deter investors may engage in regulatory competition and intentionally maintain low regulations (23, 24). To some extent, this has been true of the Chaco and Chiquitano. Paraguay's president, Horacio Cartes, infamously encouraged in 2014 the "use and abuse of Paraguay" by Brazilian investors (44). In Bolivia, the passing of law 337 that grants amnesty for past deforestation, the announcement of a plan to expand agriculture by a million hectares per year until 2020 (45), and the removal of a zealous leader of the forest administration (46) were all positive signs sent to investors. Companies also exert a direct influence on land-use policies. Agricultural lobbies pushed for less restrictive zoning maps for the Argentine "*ley de bosques*" and were influential in the rebuttal of the zero deforestation law in the Paraguayan Chaco (47).

One solution to regulatory competition and a resulting "race to the bottom" is a concerted action to harmonize regulatory frameworks through a mix of public and private initiatives. There are several avenues for public-led regulatory harmonization in the Chaco, such as the Framework Agreement on the Environment of the MERCOSUR (Mercado Común del Sur). Private-led harmonization could be achieved through the standardization of sustainable sourcing commitments across products and regions. This would require better traceability of exported products (e.g., based on a requirement to disclose product origin at the point of sale) (*Supporting Information*).

To avoid investment losses and deforestation leakage following the strengthening of deforestation regulations, governments can support sustainable agricultural intensification, focusing on practices that increase the producer's profits without causing additional harm to soils, water, or biodiversity (48). Such support would be most effective if targeted at those companies most likely to be affected by the regulations—that is, deforestation-intensive companies. This could include investments in the development and promotion by extension agencies of yield-increasing technologies and crop-livestock integration (49). Capacity building for agricultural workers in marginal areas would be required, as they suffer from shortages in skilled labor.

However, policies to enable intensification may increase agricultural rents and incentivize further agricultural expansion (3, 50). To minimize this risk, these measures need to be accompanied by strict limits to forest clearing. Policymakers should consider improving the enforcement of existing regulations, revisiting state settlement and land distribution policies to include sustainability criteria, discouraging speculative land development in forested areas, and increasing the cost of deforestation through higher administrative fees for legal clearing and higher fines and penal sanctions for illegal clearing. Raising the rent of standing forests may also help diminish incentives for conversion, for example, through existing legal avenues for payments for ecosystem services in Paraguay and Argentina (laws 3001/06 and 26.331/07, respectively), or through carbon payments.

Conclusion

Producers on agricultural commodity frontiers are increasingly mobile and responsive to expansion opportunities and constraints on land use. The hypothesis that differences in deforestation regulations encourage them to move to less-regulated agricultural frontiers raises concerns both for nature conservation, because such movements offset the benefits of conservation actions, and for governments, with the prospect of a loss of investments. Increasing deforestation regulations in parts of the Gran Chaco and Chiquitano woodlands following the rapid deforestation of the last decades have created a natural experiment to test the deforestation haven hypothesis. We found that lower deforestation regulations attract investments by agricultural companies that tend to clear more forests, and that companies are generally attracted by lower enforcement. These effects are limited and easily offset by other factors, such as proximity to current investments and availability of forestland. Addressing deforestation leakage requires a greater harmonization of deforestation regulations across regions and commodities, promoting sustainable intensification in cattle ranching and further restrictions on deforestation.

Materials and Methods

Data. We conducted semistructured interviews of soy and cattle producers in Argentina, Bolivia, and Paraguay during two field visits of 3 mo each in 2013 and 2014 (125 companies). We contacted the first companies through producer's associations and then asked these for contacts of other companies, targeting ones that had moved to or from the area. Additionally, we conducted open interviews with key informants from agricultural cooperatives and lobbies (29), industry and services (24), research and extension services (20), social and environmental NGOs (24), and government organizations (9). We retained only companies that had moved to or expanded in the Gran Chaco or Chiquitano after 1990, resulting in a sample of 118 movements by 82 companies. Movements recorded were mostly from Argentina (87 cases), with fewer from Brazil (10), Paraguay (11), Uruguay (7), and other countries (Fig. 1). These companies collectively owned over 2.5 Mha of developed and undeveloped land in the study region (Table S1). Secondary data used in the model were obtained from government agencies, international agencies, key informants, and private companies (*Supporting Information*).

Methods. To estimate the effect of deforestation regulations on the choice of location for expansion or resettlement of agricultural activities in the Chaco, we ran a nested logit model (NLM) on observations of company investments in our sample. For this we used the random utility model-consistent implementation of the nested logit regression (nlogit) in STATA. NLMs are choice models that allow the error terms of groups (or nests) of alternatives to be correlated and are therefore suited for choices with a hierarchical structure (ref. 51, pp. 808–810) [e.g., a migration choice to move to one of several macro regions and, given that choice, a decision to move to a particular area within that region (52, 53)]. The probability of a choice can be expressed as the product of the probability of a nest and the probability of a choice within that nest. In our case, the choices are provinces and the nests are countries, so that for each company and period

$$\Pr[province\ i, country\ j] \equiv P_{ij} = P_{i|j} * P_j.$$

The specification of these two probability functions is discussed in greater detail in *Supporting Information*.

From the interviews, we derived dates and locations of land investments for each company in the sample. For the choices to be comparable, we divided the observation period into four time periods (1990–1997, 1998–2002, 2003–2007, and 2008–2012) based on political and economic conditions (i.e., growth rates, export taxes, and forest policies; Table S6). Choices for each of these periods are pooled in the dataset. To be congruent with the main scale of variation of deforestation regulations, we used provinces to define the choice set and retained only those provinces occurring in the sample, resulting in 11 possible destinations. At each period, provinces where the company was already investing were excluded from the choice set.

Choice attributes included commodity producer prices, yields, land prices, transport costs, proximity to current investments (a dummy for whether the destination was a neighbor to the origin), and available agricultural land and forestland (i.e., land that could potentially be converted to cropland or ranchland). These variables were estimated separately for cattle and soy and were applied depending on the company's main activity for the new investment. Time-dependent variables were averaged over each period. Deforestation regulations in destinations were represented as the percentage of available forestland made unavailable to agricultural expansion by deforestation restrictions such as protected areas, land zoning, moratoria, and on-property set-asides (Fig. S2). The level of enforcement of regulations was represented as the product of an index of the amount of fines for illegal deforestation and an index of the quality of deforestation monitoring.

We created a variable representing the companies' propensity to acquire forested land, calculated as the proportion of all land acquired during a period under forest cover at the time of acquisition. Because these companies make no use of the woodlands, it can be assumed that they have the intention of

clearing them, so that companies that acquire more forested land will see their activities proportionately more affected by restrictions on deforestation. Alternative specifications of the model, robustness tests, details on the variables, a discussion of endogeneity, and details on the counterfactuals are provided in *Supporting Information*. The questionnaire, dataset, and code used for the nested logit model are accessible at https://purl.stanford.edu/yn536gj2686.

For the qualitative analysis of place attributes, we looked at all of the instances in which a destination was cited in the interview transcripts and searched for attributes mentioned in the same or a nearby sentence in reference to those places. All interviews relating to the companies in the sample were transcribed and coded for places and attributes of places using targeted and open coding. Places could be countries, provinces, geographical regions, or localities. Attributes were characteristics of places that made them desirable or undesirable for soy or cattle production. A typology of attributes based on economic theory was developed based on themes emerging from the interviews (*Supporting Information*). A code relation matrix showing the co-occurrence of places and attributes was used as the basis for qualitative analysis.

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