

1 **Title: Rents, actors, and the expansion of commodity frontiers in the Gran Chaco**

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22 **Abstract**

23 Theories of frontier expansion in the last four decades have been mostly shaped by studies
24 of state-driven smallholder colonization. Modern-day agricultural frontiers, however, are
25 increasingly driven by capitalized corporate agriculture operating with little direct government
26 intervention. The expansion of contemporary frontiers has been explained by the existence of
27 spatially heterogeneous “abnormal” rents, which can be caused by cheap land and labor,
28 technological innovation, lack of regulations, and a variety of other incentives. Here, we argue
29 that understanding the dynamics of these frontiers requires considering the differential ability
30 of actors to capture such rents, which depends on their access to production factors and their
31 information, preferences, and agency.

32 We propose a new conceptual framework drawing on neo-classical economics and
33 political economy, which we apply to the South American Gran Chaco, a hotspot of
34 deforestation for soy and cattle production. We divide the region into a set of distinct frontiers
35 based on satellite data, field interviews, and expert knowledge, to review the drivers and actors
36 of agricultural expansion in these frontiers. We show that frontier expansion in the Chaco
37 responded to the rents created by new agricultural technologies, infrastructure, and rising
38 producer prices, but that the frontier dynamics were strongly influenced by actors’ ability to
39 capture or influence these rents. Our findings thus highlight that understanding contemporary
40 commodity frontiers requires analyzing the novel ways by which the agency of particular
41 groups of actors shapes land-use outcomes.

42

43 Keywords: frontiers; rent; Gran Chaco; soy; cattle

44 **Introduction**

45 Humans have always sought to appropriate natural resources, and have done so in part by
46 expanding agriculture through agricultural frontiers, characterized by “the initial existence of
47 abundant land, mostly unoccupied, and by a substantial migration of capital and people” (di
48 Tella 1982). Historically, tropical agricultural frontiers operated through a reallocation of
49 smallholders to marginal areas, driven by a combination of population increase and land
50 scarcity in their areas of origin (Carr 2004; Carr, Lopez, and Bilsborrow 2010), depletion of
51 natural resources, conflicts, and mining booms, and often initiated or supported by states
52 (Rindfuss et al. 2007; Rudel 2007; De Koninck 2000).

53 Several theories have sought to explain such smallholder frontiers (Browder et al. 2008;
54 Walker et al. 2009; Godar, Tizado, Pokorny, and Johnson 2012). The capitalist penetration
55 thesis posits that frontiers correspond to the progressive spread of capitalist relations of
56 production into “non-capitalist” environments. The inter-sectoral articulation thesis analyses
57 how capital accumulation in the secondary and tertiary sectors builds on the captive labor force
58 of smallholders (Browder et al. 2008). Chayanovian models explain frontier land-use change
59 as a dynamic aggregation of household-level economic and demographic processes (Caldas et
60 al. 2007).

61 These theories generally describe frontiers as moving from a populist or pioneer stage,
62 dominated by smallholders, towards a capitalized or consolidated stage, where more powerful
63 actors consolidate land into large holdings (Foley et al. 2005; Pacheco 2005). This transition
64 can be driven by the low profitability of pioneer agriculture (e.g., due to soil degradation, poor
65 soil quality, lack of technical and financial support), leading to the formation of a “hollow
66 frontier” (Casetti and Gauthier 1977; Hecht 2005), or by a “technology treadmill”, where
67 continuing competition leads to intensification and the exclusion of laggards (Levins and
68 Cochrane 2010; Chatalova, Müller, Valentinov, and Balmann 2016). Depending on the

69 contexts, smallholders may sell their land or be expelled, and either migrate to urban areas or
70 seek cheaper land elsewhere, thereby driving further frontier expansion (Richards 2015, 2012).

71 In modern frontiers, however, the role of corporate capital and commodity agriculture
72 changes from an indirect cause of frontier expansion through the consolidation of frontiers
73 initially opened up by smallholder pioneers, to its main direct cause (Rudel 2007). This has led
74 some authors to refer to corporatist frontiers, in contrast to smallholder frontiers (Browder and
75 Godfrey 1997), although this distinction is not always clear-cut (Pacheco 2012), and some
76 contemporary frontiers can be driven by both types of farmers (Barbier 2012). Governments,
77 meanwhile, have shifted from a role of planning to one of facilitation (Rudel 2007), or of non-
78 intervention. The combination of corporate actors and the relative absence of state planning
79 gives rise to so-called neoliberal frontiers (Brannstrom 2009; Hecht 2005). In this paper, we
80 define commodity frontiers as areas where the production of agricultural commodities (such as
81 beef, soy, or palm oil) by large-scale farms expands over other land uses, and whose
82 development is shaped by the greater ability of these large-scale actors to influence and capture
83 agricultural rents. In that sense, the concept of commodity frontier overlaps with, but is distinct
84 from, that of neoliberal frontier. While the latter is defined by a neoliberal political
85 environment, commodity frontiers have continued to exist in a “post-neoliberal” era (Grugel
86 and Riggiozzi 2012). The concept of commodity frontiers also puts greater emphasis on the
87 agency of large farms, in addition to that of states and meso-level organizations (Jepson 2006).

88 The expansion of commodity frontiers is premised on the existence of an “abnormal” rent,
89 i.e. an economic rent that exceeds the bid rent or land price, generated by factors such as cheap
90 (or forced) labor, technological innovation, or legal and economic incentives (Barbier 2012; di
91 Tella 1982). As long as this extraordinary rent exists, new actors move in to exploit it, driving
92 frontier expansion. Not all actors, however, have equal access to this rent, and differences in
93 their ability to capture it determine whether and when they move in. In state-driven frontiers,

94 which are often motivated by geopolitical and other motives rather than by potential rents, these
95 differences are often dampened by targeted policies and support for actors with lower capacity.
96 In the absence of such safeguards, the presence of highly capitalized actors creates larger
97 differentials between actors. We argue that these differentials have the potential to shape land-
98 use and social outcomes more than they would in smallholder frontiers. To understand the
99 dynamics of contemporary commodity frontiers, it is therefore important to consider not only
100 the causes that increase economic rents, but also the role and characteristics of heterogeneous
101 actors, and their capacity to shape and capture those rents.

102 The objective of this paper is to analyze how the interactions between structural
103 mechanisms that create rents and the capabilities of heterogeneous agents influence the
104 development of commodity frontiers, using the case of the Gran Chaco (Figure 1), a dry
105 woodland ecoregion extending between Northern Argentina, Western Paraguay and South-
106 Eastern Bolivia, and one of the most active deforestation frontiers of the world (Baumann et al.
107 2016). Based on a review of the causes and agents of frontier expansion in the Gran Chaco, we
108 show that the interaction of rents and agentic capabilities can play out in various ways, but that
109 there are key common processes in these frontiers. We start by laying out the foundations of
110 our theoretical framework; then, we provide a short comparative history of the different
111 commodity frontiers of the Gran Chaco. Finally, we discuss the ways in which the integration
112 of actor heterogeneity helps improve our understanding of frontier expansion processes.

113

114 **Theoretical framework**

115 Agricultural frontiers are characterized by an abundance of “unoccupied” land, i.e., land
116 not yet under permanent cultivation (di Tella 1982). At equilibrium, whether land is cultivated
117 or not depends on the economic rent of agricultural vs. non-agricultural land uses, reflected in
118 the bid rent that users are willing to pay for land, which itself determines land prices (Walker

119 2004). Following von Thünen, this rent decreases with distance to agricultural markets, and the
120 transition between cultivated and uncultivated land happens where the rent of the former is
121 lower than that of the latter ((Angelsen 2010); Figure 2A). This border moves as the factors
122 influencing rents, e.g., transport and input costs or commodity prices, change. Gradual changes
123 in the rent factors, however, do not satisfactorily explain the rapid expansion of commodity
124 frontiers. For a commodity frontier to emerge, free or cheap uncultivated land must suddenly
125 acquire potential value for at least some actors through an abnormal rent (di Tella, 1982, p.212),
126 (Figure 2B). The expectation of such an exceptional rent, founded or speculative, drives
127 investments at the frontier until the bid rent catches up with the economic rent (Figure 2C).

128 Five main mechanisms may induce a sudden increase in the economic rent in commodity
129 frontiers. First, a change in accessibility, typically through the construction of roads and
130 railways, improvements in waterways, and new storage or processing facilities, will diminish
131 production costs and increase rents (Angelsen 2010). Second, a change in land productivity,
132 due to changing agro-environmental conditions (e.g., increasing rainfall or temperatures, or
133 wetland drainage), can increase the output-to-input ratio. Third, rent can increase through
134 technological innovations such as improvement in cultivation techniques, seed technology, or
135 machinery (Kaimowitz and Smith 2001; Angelsen and Kaimowitz 2001). Fourth, producer
136 prices and/or demand may change abruptly, for example when export restrictions are lifted (e.g.,
137 when a region becomes foot-and-mouth disease-free, see (Schierhorn et al. 2016)), raising
138 producer prices or allowing farmers to sell more at the same price. Finally, subsidies or other
139 policies such as tax exemptions can directly affect rents by decreasing the cost of inputs such
140 as labor, capital, or energy, or raising producer prices (Hecht 1985; Jepson 2006; Binswanger
141 1991).

142 Other processes such as agglomeration economies can support these mechanisms, as
143 clusters of farmers may benefit from the same infrastructures, spread new technologies, or

144 lobby more effectively for subsidies (Garrett, Lambin, and Naylor 2013b). Abnormal rents will
145 naturally tend towards zero under a perfectly competitive market situation with finite land
146 reserves, as more and more agents exploit them, driving demand for land, and thus land prices,
147 up. However, heterogeneous agents and imperfect markets can temporarily maintain a
148 disequilibrium between bid rent and economic rent, thus creating the conditions for commodity
149 frontiers to emerge.

150 Recent work on frontiers has examined the complex ways in which frontier expansion is
151 shaped by factors affecting incentives at different scales, but it has tended to overlook the role
152 of agent heterogeneity in frontier formation. For example, building upon rent theory and
153 political economy, Jepson (2006) used an institutional approach to show “how organizations
154 interact with the political economy (cheap credit, development programs, and subsidies) and
155 influence other important cost factors (technology, property rights, and access to markets) to
156 produce the new modern frontier in the South American tropics”. Jepson et al. (2010) further
157 developed the role of institutions such as property rights and contracts, and showed that, along
158 with organizations (firms and cooperatives), they “formed a regime of access that mediated
159 social-environmental interaction to create the conditions for [...] land-change outcomes”.
160 While this work highlights the diversity of institutional forms influencing incentives that
161 produce frontiers, it tends to treat farmers themselves as relatively homogeneous in their
162 response to these incentives.

163 High rents at the margin are not, however, a sufficient condition for frontier development.
164 If no actor is positioned or willing to act upon them, the frontier will remain unexploited. While
165 in some situations (e.g., at frontiers dominated by small-scale colonists), farmers can be treated
166 as relatively homogeneous in their response to rents and their influence on frontier
167 development, this is increasingly inaccurate in contemporary commodity frontiers. We
168 distinguish between four characteristics that differentiate actors’ response to an existing rent.

169 First, they need information on the existence and the amount of the rent. An actor with no
170 information will not invest, and an actor with insufficient information may perceive investments
171 as riskier. Second, access to land and other factors of production (including financial capital) is
172 a necessary condition for production. Third, preferences, particularly risk and time preference,
173 induce different responses for a given rent, risk level and time frame. High rents may be
174 associated with higher risks, deterring risk-averse actors, or they may require a long time to
175 materialize, which may deter actors favoring short-term returns. Finally, actors with greater
176 agency, or power to influence factors that affect agricultural rents, may invest more readily than
177 others, as they can expect some conditions to improve as a result of their actions. Examples
178 include lobbying for legal access or building transport infrastructure (Figure 2D).

179 The combination of economic rents and heterogeneous actors can explain why the rapid
180 dynamics observed on modern commodity frontiers depart from the gradual expansion
181 predicted by the von Thünen model. At an early stage of commodity frontier expansion, which
182 we call “pre-frontier” after Rodrigues et al. (2009), an economic rent is created for the reasons
183 mentioned above, but in the absence of actors with sufficient access or information to capture
184 it, it does not trigger land-use change or an increase in the bid rent (Figure 2E). During early
185 frontier development, only a limited number of actors are positioned to take advantage of the
186 rent. Initial developments generate agglomeration economies, decreasing costs, and
187 information on the rent spreads, which decreases perceived risk. The area becomes attractive to
188 new actors, and capital flows into the frontier. As this happens, land prices start rising more
189 drastically towards the point of equilibrium, and the abnormal rent decreases, along with the
190 flow of investment. This leads to a post-frontier stage when the abnormal rent disappears, and
191 agricultural expansion returns to being a function of gradual changes in population and land
192 prices.

193 The existence and magnitude of different kinds of rent factors and the presence of certain
194 types of actors, as well as the way their interactions play out in terms of frontier dynamics
195 (Figure 3), depend on local context and history. Cultural factors, historical legacies, ties to
196 global markets, or geographic particularities all shape the development of specific frontiers. In
197 the next section, we review different frontiers in the Gran Chaco, and reexamine their dynamics
198 in the light of our theoretical framework.

199

200 **Frontiers of the Gran Chaco**

201 The Gran Chaco, a dry woodland ecoregion, covers over seventy million hectares in
202 Argentina, Bolivia and Paraguay. In the last decades, the Gran Chaco has experienced among
203 the world's highest deforestation rates, with the conversion of over fourteen million hectares of
204 woodlands to agriculture between 1985 and 2013 (Baumann et al. 2016). The new wealth
205 generated by this expansion has come at a high social and environmental cost. Many of the
206 Gran Chaco's 145 mammal, 400 bird, thirty amphibian and forty-six tree species are threatened
207 (Torres, Gasparri, Blendinger, and Grau 2014), and agricultural expansion has triggered huge
208 carbon emissions (Baumann et al. 2016), and caused the displacement of indigenous
209 populations and other smallholders (e.g., Bessire 2014).

210 Agricultural expansion has occurred along several distinct frontiers. While these share
211 common causal processes and pathways, they also exhibit significant differences, e.g., in the
212 actors involved or the land uses driving expansion. To study these differences and
213 commonalities, we divided the Gran Chaco into twelve frontiers, and reviewed their recent
214 history. This analytical approach is not meant to provide a formal typology of frontier pathways,
215 but rather to facilitate the discussion of local-level dynamics.

216 We first divided the Gran Chaco (Olson et al. 2001) into hexagons of 10-km diameter, for
217 which we calculated the total area of cropland, pastures, and forests for 1985, 2000 and 2013,
218 using land-cover maps from Bauman et al. (2016). We then divided these hexagons into classes
219 of high (>66 percent), medium (33 to 66 percent) and low (<33 percent) forest cover, and high
220 (>2.5 percent), medium (1-2.5 percent) and low (<1 percent) annual deforestation rates¹ for the
221 periods 1985-2000 and 2000-2013 (Figure 4A). We considered as “active deforestation
222 frontier” (Rodrigues et al. 2009) the hexagons with a combination of high forest cover and high
223 or medium deforestation rates, or medium forest cover and high deforestation rates, assuming
224 a transition from dense forest to low-density forest and agriculture. We considered frontiers as
225 distinct when they expanded from a different geographic origin, based both on the patterns
226 observed in maps and on the authors’ knowledge, resulting in the identification of twelve
227 distinct frontiers (seven in Argentina, two in Bolivia, and three in Paraguay; Figure 4C). The
228 number and location of frontiers was robust to variations in the thresholds used to define classes
229 of high, medium and low forest cover and deforestation.

230 We characterized each frontier based on information on land-use change, sources of rent,
231 and actors involved. Interviews conducted by the first author in 2013, 2014 and 2016 form the
232 basis of our qualitative insights, along with expert knowledge of the other authors, literature,
233 and data from various government and non-government sources. Interviews were conducted
234 with 126 medium- to large-scale farmers and with key informants from agricultural
235 cooperatives and lobbies (29), industry and services (17), research and extension services (22),
236 social and environmental NGOs (29), and government organizations (13, Table 1). We used a
237 snowball sampling procedure. Farmers, contacted through producers’ associations or other
238 contacts (e.g., real-estate agents, NGO employees, or researchers), were asked to provide the
239 contacts of other producers they knew. We used key informant interviews to verify that we were
240 not missing important categories of actors. Semi-structured interviews with farmers included

241 questions about production history and methods, past land investments, and other
242 characteristics such as their relationship to other supply chain actors. Open and semi-structured
243 interviews with key informants covered a wide range of topics, from actors and dynamics of
244 frontier expansion to supply chain structure, social and environmental issues, and governance.
245 Interviews were conducted in Spanish or German (in the Mennonite colonies) and transcribed
246 subsequently. We conducted textual searches through the body of transcribed interviews to
247 generate and cross-check statements on processes and actors of land use change. Wherever
248 possible, we cite independent sources to support our evidence.

249

250 *Frontiers of Argentina*

251 The pre-frontier Chaco in Argentina long harbored *criollos* (i.e., small-scale pastoralists
252 of European and indigenous descent) and indigenous communities living from subsistence
253 farming and herding, hunting and gathering, and occasional contract work in factories and farms
254 (Miller 2001). While some commodity crops, such as white and black beans, sugar cane, cotton,
255 wheat, sorghum and corn, had encroached timidly into the Gran Chaco in earlier decades
256 (Morello, Pengue, and Rodriguez 2005), frontier expansion took off with the 1990s' soy boom
257 (Grau, Gasparri, and Aide 2005), caused by increasing global demand and rising prices for soy,
258 and the adoption of no-till cropping and genetically modified (GM) soy seeds in the mid-1990s,
259 in the context of a long-term increase in rainfall (Delvenne, Vasen, and Vara 2013; Grau,
260 Gasparri, and Aide 2005; Hoyos et al. 2013; Zak, Cabido, Cáceres, and Díaz 2008). No-till
261 cropping allowed for higher water retention in soils, a key factor in dry environments, and its
262 spread was enabled by the development of Glyphosate-resistant GM soy, which removed the
263 need to till the soil for weed control (Qaim and Traxler 2005). The introduction of storage bags
264 in the mid-1990s also supported expansion into areas without proper storage infrastructure
265 (Goldfarb and van der Haar 2015). Soy cultivation displaced cattle ranching from the Humid

266 Pampas, a grassland ecoregion of Central Argentina (Figure 1) to the Chaco, and provided soy
267 farmers with surplus capital to reinvest in expansion (Viglizzo et al. 2011). The expansion of
268 cattle ranching was also supported by growing meat demand and improved pasture varieties. In
269 2001, following the Argentine economic crisis, currency devaluation lowered production costs
270 (mostly borne in pesos) relative to export prices, increasing profits from soy exports (Gasparri
271 and Grau 2009). The government granted farmers the payment in pesos of debts contracted in
272 dollars, which in effect dramatically reduced these debts (Cáceres 2015). In parallel, a loss of
273 trust in the banking system provoked a massive redirection of capital towards agriculture,
274 considered a safer investment. These conditions triggered a second soy boom that led to further
275 expansion in the Argentine Chaco (Gasparri, Grau, and Gutiérrez Angonese 2013).

276 Argentine frontiers expanded from consolidated agricultural areas in humid regions
277 towards the drier parts of the Chaco. In this process, criollos and indigenous communities were
278 displaced further into the Chaco (Goldfarb and van der Haar 2015), migrated to towns and cities
279 (Sacchi and Gasparri 2015; Vivaldi 2011) or integrated the frontier economy as agricultural
280 workers, e.g., for forest clearing (Paolasso, Krapovickas, and Gasparri 2012). Service providers
281 from the Pampas followed pioneers, some of them buying land and becoming farmers
282 themselves. Multinational corporations progressively replaced local grain traders, and
283 numerous medium-scale pioneer farms, unable to withstand growing competition, were
284 consolidated into larger farms.

285 The frontiers of Córdoba, Bandera and Chaco-Santiago (1-3 on Figure 4C; Figure 5),
286 separated from each other by a series of vast saline depressions, expanded north- and westwards
287 along a decreasing rainfall gradient (Zak, Cabido, and Hodgson 2004; Gasparri, Grau, and
288 Sacchi 2015; Hoyos et al. 2013). Agricultural expansion in the northeast of Córdoba took off
289 in the mid-1990s when the soy boom displaced cattle ranching from the Pampas and created a
290 sudden abundance of capital that led farmers to seek new investment outlets. Pioneers met

291 limited resistance from criollo populations, though agricultural expansion was met with fierce
292 opposition from urban civil society (Cáceres 2015). Soy gradually replaced pastures (Table 2,
293 Figure 4B), thanks in part to an increase in rainfall, except in northwest Córdoba where no such
294 increase occurred (Hoyos et al. 2013). In the water-deficient west, recent expansion was caused
295 mostly by selective logging for fuelwood and charcoal production, with some cattle ranching
296 and irrigated cultivation.

297 Bandera's agricultural development dates back to the arrival in the early 1990s of small-
298 scale farmers, many of them affiliated to an agricultural cooperative in northern Santa Fe
299 (Avellaneda), and some from the Pampas of Córdoba. A wave of larger investors from the
300 Pampas arrived in the 2000s, while transnational commodity traders established offices in the
301 area. Bandera's development follows the same pattern as Córdoba's, with an early expansion
302 as a cattle frontier followed by a soy boom from the mid-1990s on. By the late 2000s, many of
303 the original pioneers had sold or leased their land to larger companies and returned home, for
304 either economic or personal reasons.

305 Further North, the Chaco-Santiago frontier expanded along roads 16 and 89 into two
306 provinces with markedly different social and political contexts. Santiago del Estero (Figure 1),
307 with large undeveloped properties, ongoing social conflicts, and weak governance, had little
308 agriculture before the soy boom. Chaco province had smaller properties, a stronger rule of law,
309 and a longer legacy of agriculture. A cotton boom in the late 1980s caused a first influx of
310 investment from Buenos Aires and Córdoba to the Chaco province, speeding up deforestation.
311 Following several harvest failures in the mid-1990s, cotton gave way to soy as the primary
312 driver of this agricultural expansion (Abel Gómez 2014). The proximity to booming agricultural
313 clusters in the Chaco province made the large undeveloped properties of Santiago del Estero
314 increasingly attractive, and in the 2000s, more outside investors appeared, many of them from

315 Córdoba, driving crops and pastures further west into the dry Chaco, and exacerbating existing
316 conflicts (Goldfarb and van der Haar 2015).

317 Frontiers of Argentina's *Umbral al Chaco* (4-6 in Figure 4C) are characterized by a
318 westward gradient of increasing rainfall due to the presence of the sierras and pre-Andean
319 mountains. Initial agricultural developments occurred in the wetter foothills of Tucumán, Jujuy
320 and Salta for the cultivation of sugar cane, followed by a limited expansion north- and eastwards
321 of white and black bean cultivation in the 1970s, after all land suitable for sugar cane had been
322 settled. Faster expansion into the Chaco, east of the main north-south road axis (roads 5 and
323 34), is more recent, and mostly related to soy cultivation.

324 Tucumán's agricultural experimentation center, the Estación Experimental
325 Agroindustrial Obispo Colombres, had a pivotal role in the development of new soy varieties
326 in Argentina. By 1985, Tucumán's frontier had already extended to towns in the South of Salta
327 province (Metán, Rosario de la Frontera), and sugar cane had colonized all areas with sufficient
328 rainfall. In the 1990s, eastward expansion beyond these areas was driven by local sugar cane
329 farmers diversifying into soy and cattle production, and by the displacement of cattle by soy
330 farming. In the 2000s, more farmers bought and developed land across provincial borders,
331 particularly in western Santiago del Estero following the pavement of road 34 in 2005, but also
332 in Catamarca and Salta. Unlike farmers from Córdoba or Buenos Aires, they mostly favored
333 areas close to Tucumán, and few jumped to other frontiers.

334 Anta's development beyond the wetter foothills took off in the 1980s with early forest
335 clearings for cattle ranching and bean production by family companies from Salta, Jujuy and
336 Buenos Aires. With the first soy boom, expansion quickened and new actors appeared, notably
337 foreign companies which, although not numerous, acquired large quantities of land. Anta had
338 very large properties of up to tens of thousands of hectares, favoring large investments, and a
339 powerful landed elite, mostly from Salta. Towards the end of the 2000s, expansion was almost

340 exclusively driven by cattle ranching, as most of the land suitable for cultivation was already in
341 use.

342 The agricultural frontier in Tartagal is an eastward extension of the colonization of the
343 moist Yunga forests in the Andean foothills during the 1980s and 1990s (Brown and Malizia
344 2004), facilitated by a network of trails left by petroleum exploration (Morello 2005). The area
345 has been an important producer of beans in addition to soy and cattle, and croplands, rather than
346 pastures, remain the primary driver of expansion (Figures 4B & 5, Table 2). Bound by the
347 Bermejo and Pilcomayo rivers, the region has strong indigenous and criollo presence, which
348 has led to the majority of the area being designated as a zone of restricted agricultural
349 development under the 2007 forest law (*ley de bosques*, law 26,331).

350 Finally, Formosa is the most recent agricultural frontier in the Argentine Chaco,
351 expanding alongside road 81 and limited to the north by the Río Pilcomayo, and to the south by
352 the Río Bermejo. Long ignored by industrial agriculture because of its uneven soil quality, its
353 inaccessibility, the prevalence of diseases, and the high flood risk, it became more attractive in
354 the late 2000s as land elsewhere was getting scarcer and the completion of road 81 (in 2009)
355 improved accessibility. Experiments with improved pastures, conducted in the 1990s and 2000s
356 by the Centro de Validación de Tecnologías Agropecuarias (CEDEVA), and laxer
357 environmental regulations than in neighboring provinces, may have incentivized expansion (le
358 Polain de Waroux, Garrett, Heilmayr, and Lambin 2016). Almost exclusively a cattle frontier
359 (Figure 4B & 5, Table 2), Formosa was developed by farmers from the Córdoba, Buenos Aires,
360 and to a lesser extent, Chaco provinces. Holding the largest indigenous population in the
361 country, the area has similar social conflicts to the Tartagal and Chaco-Santiago frontiers, but
362 with lower visibility and less legal protection, even though land titles were delivered relatively
363 early to indigenous communities.

364

365 *Frontiers of Bolivia*

366 The Santa Cruz lowlands, traditionally a sugar cane production area, extend eastwards
367 from the pre-Andes in a triangle of highly fertile alluvial land with moderate rainfall, limited to
368 the north by more humid areas, to the east by the infertile Brazilian shield, and to the south and
369 southeast by decreasing rainfall² (Müller, Müller, Schierhorn, Gerold, et al. 2011). Starting in
370 1985, structural adjustment led to currency devaluation, reduced tariffs and suppression of price
371 controls, preferential access to Andean markets, and liberalization of land markets (Kaimowitz,
372 Thiele, and Pacheco 1999; Pacheco 2006). These changes, along with extremely cheap land
373 (Zoomers 2003); abundant private capital from the coca, timber and gas industries and from
374 Brazilian investors (Kaimowitz, Thiele, and Pacheco 1999; Hecht 2005); new transport and
375 storage infrastructure (Pacheco 2006); and improved agricultural technologies, including no-
376 till cropping and new soy and grass varieties (Pérez Luna 2007), unleashed an era of rapid
377 deforestation, which the 1996 agrarian reform further incentivized by making land rights
378 conditional on productive use (Redo, Millington, and Hindery 2011).

379 A first phase of soy expansion in the early 1990's was largely driven by farmers from
380 Mato Grosso do Sul and Paraná (Figure 1) fleeing extreme inflation in Brazil. Mennonite
381 colonies also opened up new areas, albeit with a different model, based on clusters of small-
382 scale properties under intensive use in isolated locations. Bolivian farmers were less involved,
383 and while some thrived, many ended up selling or leasing their land (McKay and Colque 2015).
384 In the late 1990s, several consecutive harvest failures, combined with a credit crisis and
385 plummeting global soy prices, drove many farmers out of business. Amidst collapsing land
386 prices, numerous Brazilian farms were acquired by Bolivian companies or claimed by creditors
387 (Killeen et al. 2008). Meanwhile, in the 2000s, Argentine companies, mostly from the Pampas,
388 participated in a second Bolivian soy boom, with a production model based on the outsourcing
389 of services such as spraying or harvesting (Urioste 2012). Cattle ranching dominated expansion

390 during this second period (Table 2, Figure 5), both because of the aridity and lower fertility of
391 the remaining land, and because of the conversion to pastures of areas no longer suitable for
392 crop cultivation (Müller, Pacheco, and Montero 2014).

393 The small frontier of the Bolivian Andean Foothills is limited by decreasing rainfall to
394 the east, leaving a narrow strip of suitable land, much of which is protected under the Kaa-Iya
395 National Park and indigenous reserves. As in neighboring Tartagal, petroleum exploration has
396 left a grid of roads that facilitate access. Mennonite colonies have established mixed agricultural
397 production in some areas, and Bolivian ranchers practice extensive cattle ranching (Müller,
398 Larrea-Alcázar, Cuéllar, and Espinoza 2014). Recently, increasing numbers of Santa Cruz
399 ranchers acquired ranchland, benefiting from low land prices, improved pasture varieties and
400 new water storage technology.

401

402 *Frontiers of Paraguay*

403 The Paraguayan Chaco is characterized by a westward gradient of decreasing rainfall, and
404 limited by the rivers Paraguay and Pilcomayo to the east and southwest, and by sandy soils to
405 the northwest. Indigenous communities have since the 1920s shared this territory with
406 Mennonite colonists from Canada, Russia and Germany. With most of the land in private hands
407 since its distribution to foreign investors after the Triple Alliance war (Vázquez 2013; Caldas,
408 Goodin, Sherwood, Krauer, et al. 2013), extremely cheap land, and a quasi-absence of the State,
409 the Paraguayan Chaco has been a haven for large-scale speculative investments. In the 1990s,
410 research conducted locally on drought-resistant pastures, and new Brazilian deforestation
411 techniques using chains spanned between bulldozers, enabled fast expansion of cattle ranching.
412 In the 2000s, improvements in sanitary conditions, the eradication of foot-and-mouth disease
413 (in 2005, (Reuters 2005)), improved water storage technology, and the construction of new
414 export-grade slaughterhouses and acquisition of older ones by Brazilian companies with tight

415 links to international markets (Velázquez 2012), supported a boom in beef production for
416 export. Prospects of a highly profitable beef sector, advertised in the 2006 “National Meat Plan”
417 (Brusquetti and Vasconcellos 2006), incentivized national banks endowed with large amounts
418 of capital from the Eastern Paraguayan soy boom to support investments in the Chaco. The
419 2004 “zero-deforestation law” in Paraguay’s Atlantic Forest (law 2,524) may also have
420 displaced some cattle ranching to the Chaco. Finally, Mennonite colonies acted as a service hub
421 for outsiders whom the highly-developed infrastructure and service industry enabled to manage
422 ranches remotely. The development of the Paraguayan Chaco led to important social and
423 demographic changes, with indigenous populations being pushed into settlements (Bessire
424 2014), and contract workers from Eastern Paraguay and Brazil progressively outnumbering
425 Mennonites in the colonies.

426 The development of Paraguay’s Central Chaco frontier (Figure 4C, 10) started in the first
427 half of the 20th century with the first Mennonite settlements (Loma Plata in 1927, Filadelfia in
428 1930). The expansion of pastures around the colonies was quickened by the introduction of new
429 tropical grasses, such as *Panicum maximum*, in the mid-1980s, and the commercial success of
430 milk production, leading to the acquisition by Mennonite cooperatives of large properties for
431 planned colonization. In the 2000s, Mennonites also increasingly managed foreign-owned
432 farms. The cooperatives maintained roads and built their own slaughterhouses in the Central
433 Chaco and close to Asunción.

434 The Paraguayan Semiarid Chaco (Figure 4C, 11), close to the Mennonite colonies, but
435 removed from their early developments, experienced an influx of investments by French and
436 German companies in the 1980s (Vázquez, 2013; p.154). Following the expansion of the
437 Central Chaco frontier, numerous national and foreign companies started investing in the area,
438 which enjoyed the proximity to the colonies’ infrastructure, but with lower land prices. In the
439 late 2000s, an Argentine company was starting to experiment with large-scale soy production.

440 Finally, the Chaco-Pantanal frontier (Figure 4C, 12), a region with very fertile soils and
441 high rainfall, was initiated in the late 1990s by large-scale ranchers from the Brazilian states of
442 Mato Grosso do Sul and São Paulo (Figure 1), who took advantage of the area's proximity to
443 Brazil and the Mennonite colonies. In the 2000s, Eastern Paraguayan cattle ranchers followed
444 their lead, as did many non-agricultural companies. In the late 2000s, as Argentinians flooded
445 the Uruguayan land market (Piñeiro 2012), increasing numbers of Uruguayan investors
446 (González 2013), and by 2016, also a few Argentine companies, appeared. The Korean
447 Reverend Sun Myung Moon's Unification Church also purchased 600,000 ha of land in 2000
448 through its company "La Victoria" (Vázquez 2013).

449

450 **Rents, actors, and frontier expansion in the Gran Chaco**

451 *Causes of high agricultural rents*

452 While there is no quantitative data on the value of economic rents, statements from our
453 interviews provide ample anecdotal evidence that they far exceeded the low land prices in early
454 frontiers (Figure 5), e.g., "there wasn't land of such fertility for such ridiculously low prices
455 anywhere else in the world", (interview with a Uruguayan cattle rancher in the Chaco-Pantanal
456 frontier, 10/21/2013), or "in 3, 4 years, you recoup your investment — that's why we're here"
457 (interview with an Argentine farmer in the Santa Cruz frontier, 08/04/2013). Technological
458 innovation was arguably the major source of such rents in the Gran Chaco (Table 2). GM soy
459 and no-till cropping enabled expansion in Argentina and Bolivia, and new pasture varieties
460 were essential to the growth of the cattle sector, particularly in Paraguay. Booming soy prices
461 in the late 1990s and mid-2000s, combined with currency devaluation, strongly incentivized
462 soy expansion, since soy was sold in dollars but most production costs were paid in local
463 currencies. A boom in Paraguayan beef exports significantly raised producer prices. Apart from
464 cheap loans for Bolivian agriculture in the late 1980s, there were few direct subsidies to

465 agriculture, although macro-economic policies such as currency devaluation, the suppression
466 of export taxes and reduction of tariffs in Bolivia after 1985, or the repayment in pesos of dollar
467 debts in Argentina after 2001, can be regarded as indirect subsidies. Thus, even in the
468 “neoliberal” era, the State played an important role in generating rents through tax and monetary
469 policies. While increased rainfall and improved accessibility were crucial to expansion, these
470 changes were mostly gradual, and in the case of roads, often endogenous to expansion, and they
471 acted as predisposing factors, rather than triggers, for development.

472

473 *Actors and their characteristics*

474 Economic rents driving frontier expansion are sustained when forces of friction,
475 determined by the differential ability of actors to capture these rents, prevent land prices from
476 catching up. Here we propose a typology of actors, followed by a discussion of the role of
477 differences in access, information, preferences and agency in generating these frictions.

478 Commodity producers, the principal direct agents of frontier expansion, can be divided
479 into three categories. *Established farmers* are farmers from an earlier wave of expansion who
480 produce commodity crops in or near the frontier, e.g., Bolivian farmers in Santa Cruz before
481 the soy boom, Mennonite ranchers in Central Chaco, or small-scale farmers in Chaco-Santiago.
482 They have access to land and information on local conditions, but are often constrained in other
483 aspects, e.g., a lack of financial or technological capital and access to market information, or
484 unfavorable preferences (e.g. risk aversion). *Pioneers* are farmers from other regions who move
485 to a frontier at early stages, such as the farmers from Córdoba in Chaco-Santiago, or Brazilian
486 ranchers in Chaco-Pantanal. Their higher risk-tolerance enables them to “activate” frontiers in
487 information-poor environments by bringing financial, technical and social capital to marginal
488 areas. The more risk-averse *latecomers* appear when uncertainty on rents is lower, and

489 infrastructure better, and tend to focus on the colonization of the “internal” frontier, the forest
490 remnants.

491 Besides producers, several categories of actors play a less direct, but equally important
492 role in frontier expansion. *Speculators* derive profits from the increase in land prices associated
493 with frontier development. They often overlap with pioneers, arriving when prices are low, and
494 acquiring land that they sell for a premium to latecomers, often after developing it. Their main
495 assets are financial capital and information. *Rentiers* lease land to farmers. They are often
496 established farmers or pioneers outcompeted by newer arriviers. *Service providers* clear land,
497 sow crops, spread herbicides, and harvest, store and transport commodities. Rather than
498 investing in land, they acquire machinery and agricultural inputs, often spearheading the arrival
499 of major service providers and becoming their representatives. *Commodity traders and*
500 *corporations* buy, process and export commodities, and often also provide inputs and credit to
501 farmers. *Agricultural workers* provide labor for agricultural production. *Smallholders*,
502 including indigenous and criollo populations, live from small-scale farming and herding,
503 hunting, gathering, fishing, charcoal production and contract work. Poor, mostly without land
504 titles, they are generally displaced by frontier development, except where they can secure land
505 titles, as in parts of Bolivia and Argentina, or integrate commodity agriculture as labor. Finally,
506 *government bodies* build roads, set taxes, tariffs and subsidies, allocate land rights, and regulate
507 land use, *research and extension agencies* generate technology and information on local
508 conditions, and *farmers’ associations* transfer information through social networks, and lobby
509 governments for changes. Below, we focus on the characteristics of commodity producers, and
510 the ways in which their differences influence their ability to capture and influence rents.

511

512

513

514 *The role of access*

515 Differential access to land, capital, technology, and production networks, allows some
516 actors to capture rents inaccessible to others. Availability of capital from agriculture or other
517 activities, for example, was common to many pioneers, including farmers from the Pampas
518 investing in the Argentine Chaco, and Brazilian and Uruguayan investors in Paraguay
519 (González 2013). Differential access to credit has also been invoked to explain the success of
520 foreign farmers in Santa Cruz in the 1990s. In the 2000s, in a context of greater credit scarcity,
521 commodity traders came to play an increasingly important role in the financing of farmers, and
522 thus in access to financial capital.

523 Additionally, pioneers often had better access to technological capital and know-how,
524 e.g., Brazilian farmers' advanced agricultural technologies, in part the result of the Brazilian
525 government's investments in agricultural research and development through its Agricultural
526 Research Corporation (Embrapa), or Argentine famers' highly-efficient, service-based
527 management models. In some cases, a combination of local and "imported" know-how enabled
528 farmers to capture rents, e.g., new pastures and cattle breeds developed by Mennonites in
529 Paraguay, and Brazilian ranchers' ability for large-scale management and access to capital and
530 markets. Continuous technological improvement could also function as a "technology
531 treadmill", keeping newcomers out.

532 Access to land for large and foreign farms improved with neoliberal policies in the 1990s,
533 but suffered setbacks under left-wing governments in the 2000s. Land ownership in the
534 Argentine and Paraguayan Chaco was overwhelmingly private (Nolte, le Polain de Waroux,
535 Munger, Reis, et al. 2017). In Bolivia, where public and indigenous ownership dominate, the
536 1990s' neoliberal turn led to the distribution of land titles to large-scale commercial farmers
537 (Pacheco 2006). The government, however, maintained an ambiguous relationship to
538 commercial farming, tolerating a powerful agricultural elite while supporting smallholder

539 opposition (Colque 2014) and prohibiting land purchases by foreigners (National Constitution,
540 art. 396). Paraguay's 2005 prohibition of foreign land acquisitions in border areas on grounds
541 of national sovereignty (Law 2,532) may have harmed Brazilian agriculture in the Chaco-
542 Pantanal frontier, although land distributed in the context of Paraguay's agrarian reform was
543 hardly regulated (Glauser 2009). Argentina imposed quotas on foreign ownership of land in
544 2011 (Law 26.737), but this measure did not affect the main actors of land acquisitions in the
545 Chaco, who were nationals.

546 The "stickiness" of trade relations creates differences in access to production networks,
547 especially for relational value chains (e.g. beef), in which trust and shared norms are an
548 important part of the exchange (Gereffi, Humphrey, and Sturgeon 2005). Small or traditional
549 ranchers in the Chaco often sold to complex chains of local traders catering to regional markets,
550 while large, modern ones often sold to industrialized slaughterhouses that required higher
551 traceability, could handle larger volumes, and catered to international markets. Both
552 transactions involved high levels of trust, but the formalization of norms by large
553 slaughterhouses made it easier for actors able to meet them to gain trust and enter new markets.

554 Finally, alliances and contracts, formal or not, can facilitate access (W. Jepson,
555 Brannstrom, and Filippi 2010; Garrett, Lambin, and Naylor 2013a). Companies with ties to
556 local or national governments enjoyed preferential access to public lands, often under irregular
557 conditions (e.g., Morini 2011). Local name-bearers for foreign businesses (common in Bolivia
558 and Paraguay), or formal leasing contracts (common in the Argentine Chaco), improved access
559 to land for outsiders. Contracts between absentee landowners and local managers (e.g.
560 Uruguayan companies and Mennonite managers) allowed the former to capture rents without
561 know-how or on-site presence. In the presence of power inequalities and information
562 asymmetries between commercial farmers and smallholders, the formalization of land tenure

563 also secured access to land for the former, facilitating ‘land grabs’ and the dispossession of
564 smallholders (Goldfarb and van der Haar 2015; Cáceres 2015; de L.T. Oliveira 2013).

565

566 *The role of information*

567 In the absence of information, potentially lucrative investments at the frontier originally
568 go unnoticed or are considered too risky for most. Chaco pioneers relied on direct observation,
569 hearsay, and comparisons to assess land productivity and climate conditions, and they used
570 knowledge of market, institutional and access conditions to estimate potential rents. Their first
571 experiences generated a limited body of information that decreased uncertainty, and thus
572 perceived risk, for others. The selective transfer of information through social networks
573 participated in the creation of cohorts of farmers following each other’s footsteps into new
574 frontiers, while putting outsiders at a disadvantage.

575 Information asymmetries among actors made prospection a crucial activity: pioneers and
576 speculators were always on the lookout for new opportunities, constantly learning about places,
577 market conditions, and potential returns on investments. In the early 2010s, it was common
578 among Chaco farmers to pay prospective visits to other South American countries, or even to
579 Africa. Experienced pioneers could take advantage of their greater knowledge by brokering
580 land deals or managing farms for less-experienced landowners. Respected pioneers created an
581 expectation of high profits that triggered investments by their peers, even if expectations were
582 unmatched by actual rents.

583 As commodity frontiers expanded, access to information became less dependent on
584 specific social ties. Success stories in the media put the new frontiers on the map for the larger
585 public, e.g. the Bolivian lowlands for Brazilians (Klintowitz 1995) and Argentines (Lorenzatti
586 2007), or the Paraguayan Chaco for Uruguayans (Farías 2012). Prominent farmers were equally

587 important in spreading success narratives (e.g. Muñoz 2015; Artagaveytia 2011), in part with
588 the intention to reap the benefits of land appreciation (through land sales) and agglomeration
589 economies (through lower production costs). Governments too publicized the Chaco for outside
590 investors, e.g., with the Paraguayan National Meat Plan, and extension agencies or farmers'
591 associations frequently provided information to outsiders on local investment conditions. Thus,
592 government institutions contributed to the erosion of information asymmetries, which
593 accelerated expansion, increased competition and contributed to closing the gap between
594 economic and bid rent.

595

596 *The role of preferences*

597 Farmers' preferences positioned them differently in front of equal potential rents. Risk
598 preference differentiated (risk-tolerant) pioneers from (risk-averse) latecomers. Greater risk
599 tolerance could result from an availability of enough backup capital to withstand failure,
600 especially for large, multi-site companies, or from a lack of options, as for medium-size farmers
601 driven away by competition and divided landholdings. Some companies used investment
602 portfolios to buffer risks, acting as pioneers in some areas and as latecomers in others.

603 Management styles differed markedly between cohorts of farmers, shaping their attitudes
604 towards specific frontiers. Brazilian farmers often specialized in large-scale investments with
605 full ownership of factors of production, which allowed them to settle in remote places, such as
606 the Chaco-Pantanal frontier, or Santa Cruz in the early 1990s. Argentine farmers tended to
607 outsource most services and were thus more dependent on infrastructure and service providers,
608 which may explain the late development of Formosa. Mennonites, who expanded mostly
609 through the acquisition of land by cooperatives, sought vast expanses of land in remote places
610 for subdivision among their members, though some more entrepreneurial Paraguayan
611 Mennonites started buying land individually in the 2000s. Management preferences also

612 differed between cattle ranchers and soy farmers, the latter being much more dependent on the
613 proximity to agricultural clusters than the former.

614 Cultural and lifestyle preferences mattered, too. For many, being a pioneer implied
615 leaving a familiar cultural context for a more challenging social and physical environment.
616 Familiarity made places “legible” — in Santa Cruz, Brazilians were said to prefer wetter, and
617 Argentines, drier areas, more similar to their respective homes. On the contrary, cultural
618 “otherness” often generated confusion and frustration, to a point that could discourage
619 investors. Farmers from the Pampas, for example, frequently complained about the difficulty
620 of raising a family in the “backwards” towns of the Chaco.

621

622 *The role of agency*

623 One particularity of commodity frontiers of the Chaco was the ability of certain actors or
624 groups of actors to influence agricultural rents and modify their own access to these rents, e.g.,
625 by building their own roads, investing in technological improvements, lobbying governments
626 for legal access, or capturing different levels in the supply chain. Actors were thus differentiated
627 not only by the rent immediately accessible to them, but also by the rent they could expect to
628 access in the future, given their ability to overcome specific constraints (see Figure 2D).
629 Politically powerful actors, for example, could expect to access land that others could not.
630 Government officials and their allies acquired enormous amounts of land in Anta, the Central
631 Paraguayan Chaco, or Santa Cruz, and large-scale farmers lobbied successfully for the
632 downgrading of zoning plans that limited deforestation in Argentina. Farmers with enough
633 capital also opened their own access roads, or built grain silos, traded inputs and acquired
634 slaughterhouses to capture rents at other levels of the supply chain and improve the profitability
635 of their own activities.

636 Greater agency was often achieved through alliances, such as farmers' organizations or
637 cooperatives, similarly to the situation in the Brazilian Cerrado (Jepson 2006). Major roads in
638 the Paraguayan Chaco, such as the one linking Mennonite colonies to the Chaco-Pantanal
639 frontier, were built and maintained by consortia of farmers who managed machines and labor,
640 and imposed tolls and use rules. Cooperatives facilitated land acquisition and development by
641 small farmers, as with the Avellaneda cooperative in Bandera, or with Mennonite cooperatives
642 in Paraguay and Bolivia. Other farmers' associations engaged in research, prospection and
643 experimentation in ways that were inaccessible to isolated farmers. Groups of the *Consortio*
644 *Regional de Experimentación Agraria* (CREA groups), for example, an organization focused
645 on innovation in agriculture, regularly invited experts from other countries, facilitating
646 technology transfer to their members (Gras and Hernández 2016) (similar to the role of
647 APROSOJA in Brazil (Empinotti 2015)). Finally, medium-sized farmers from the Pampas or
648 Uruguay created consortiums of investors to generate economies of scale — e.g. in the purchase
649 of land and machinery — that made investments in distant Bolivia or Paraguay possible.

650

651 *Common dynamics of frontier expansion*

652 Despite differences in the causes of rents and the actors driving expansion, frontiers of the
653 Gran Chaco underwent relatively similar trajectories. High rents in early frontier stages were
654 captured by a limited number of actors, usually outsiders with capital (e.g., from the soy boom)
655 and technology (e.g., deforestation techniques), high risk-tolerance, and sufficient agency to
656 alter some of the conditions of production (e.g., accessibility, storing and processing facilities)
657 or political access. Pioneers maintained a competitive advantage through selective information
658 sharing, political exclusion, or technological innovation. Ultimately though, once established,
659 pioneers participated in the diffusion of information in order to fasten expansion and generate
660 speculative benefits and/or agglomeration economies. Land prices boomed as a result (Figure

661 5), reflecting growing expectations of rents. As agricultural clusters developed, competition for
662 land rose and land prices caught up with rents, ending the disequilibrium.

663 Taking actor characteristics into consideration in the explanation of frontier dynamics in
664 the Chaco is particularly important at the early stages of frontier development, for three main
665 reasons. First, the ability of certain actors to influence rents makes the emergence of commodity
666 frontiers less predictable based solely on structural factors. Second, mobile actors can embody
667 a link between distant places, allowing for explanations that transcend local drivers. Chaco
668 frontiers were triggered not only by local changes, but also, and especially, by the arrival of
669 new actors responding to changes elsewhere (e.g., sudden capital availability or deteriorating
670 economic conditions). Third, differential access to rents creates the friction necessary to delay
671 a return to equilibrium, generating the nonlinear expansion dynamics observed on commodity
672 frontiers. We argue that selective transfer of information along social networks was an essential
673 mechanism in maintaining these frictions in the Gran Chaco.

674

675 **Conclusion**

676 Commodity frontiers are expanding into the last remaining undeveloped agricultural land
677 on the planet. While this expansion constitutes a continuation of historical processes, the forms
678 it takes and the actors that drive it are changing. In the 1960s and 1970s, many governments in
679 the Global South directly supported the settlement of frontiers for geopolitical and demographic
680 reasons (Rudel 2007) via colonization plans, land reforms, credit schemes, infrastructure
681 investments, or technological packages. With the 1980s' neoliberal turn in South America,
682 governments largely disengaged from planned settlement, leaving a void that was filled by
683 private actors (and non-governmental organizations, see Brannstrom (2005)), who benefitted
684 from previous infrastructure investments, and from policies generating new rents. Among these
685 were regulation and enforcement of land rights (de L.T. Oliveira 2013), legal protection of

686 foreign investments (McKay and Colque 2015), legalization of technological innovations such
687 as GM soy, or macro-economic policies, such as the removal of trade barriers and currency
688 devaluation. In the 2000s' "post-neoliberal" era (Grugel and Riggirozzi 2012), the rise of left-
689 wing governments in several South American countries signaled a shift to more ambiguous
690 attitudes towards large-scale farming. The governments of the Kirchners' Argentina, Lula's
691 Brazil, Lugo's Paraguay or Morales's Bolivia acquired legitimacy with their base by adopting
692 policies to defend smallholder and indigenous rights, tax commercial agriculture and curb
693 deforestation and foreign land acquisitions, while continuing to support, or at least tolerate, a
694 powerful agricultural sector on which they depended (Cáceres 2015).

695 This changing role of the state and the emergence of large-scale commodity farms as major
696 drivers of frontier expansion, while not uniform across the region (see Pacheco (2009)), have
697 consequences for how we conceptualize contemporary frontiers. The Gran Chaco shows how
698 their advance is shaped by the existence of abnormal economic rents and by the presence of
699 actors able to capture these rents. In contrast to a classical view of frontiers, where actors are
700 largely responsive to structural changes often initiated by governments, commodity frontiers of
701 the Gran Chaco were characterized by large differences in the ability of actor groups to capture
702 and influence rents, and to strategically manipulate conditions of access. This differential ability
703 is related to different endowments in terms of information and access to capital, land,
704 technology or markets, which determine their role and position in the process.

705 Based on our review of frontiers of the Gran Chaco, we propose that dynamics of
706 commodity frontier expansion are characterized by 1) the prevalence of a limited number of
707 actors with the ability to influence rents and access; 2) the mobility of actors across regions and
708 countries, enabling distant causal interactions, including transfers of knowledge and capital;
709 and 3) the importance of the creation and selective transfer of information about agricultural
710 rents in creating and maintaining access differentials. The rent-actor typology proposed here

711 attempts to represent these dynamics by combining agentic and structural explanations of
712 frontier development. As such, it builds upon existing efforts to overcome the limitations of bid
713 rent theory and better represent agent-level and political/institutional dynamics in theories of
714 land-use change (Walker 2004; Jepson 2006; W. E. Jepson, Brannstrom, and Filippi 2010) by
715 incorporating the notions agent-level heterogeneity and disequilibrium as determinants of
716 agricultural expansion. This is important if we are to better anticipate the emergence and
717 development of new commodity frontiers, and the associated social and environmental
718 challenges they might bring.

719 **Notes**

720 1) Calculated as $D = 100 * \frac{1}{t_2 - t_1} * \frac{F_{t_2} - F_{t_1}}{F_{t_1}}$, with F the forest area.

721 2) *Santa Cruz* is only partially in the Chaco ecoregion; its Northern part pertains to the
722 more humid Chiquitano forest.

723

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733

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1005 **Figure Captions**

1006

1007 Figure 1: Study area and main places mentioned in the paper. Administrative units (provinces,

1008 departments, states): BA = Buenos Aires; CA = Catamarca; CO = Córdoba; CH = Chaco; JU

1009 = Jujuy; FO = Formosa; MS = Mato Grosso do Sul; PR = Paraná ; SA = Salta; SC = Santa

1010 Cruz; SE = Santiago del Estero; SF = Santa Fe; SP = São Paulo; TU = Tucumán. “S.C. de la

1011 Sierra” is Santa Cruz de la Sierra, and “S.M. de Tucumán” is San Miguel de Tucumán. The

1012 Humid Pampas are indicated as one region from which multiple actors in the Chaco frontiers

1013 originate.

1014 Figure 2: Rents and dynamics of frontier expansion. A & C: Pre- and post-frontier equilibrium

1015 where bid rent equals economic rent, and the transition to uncultivated land (f) happens where

1016 rent is zero (assuming zero rent for uncultivated land). B: Frontier situation where the

1017 economic rent exceeds the bid rent, generating an “abnormal” rent and a frontier space F

1018 where expansion may happen. D: Rent curves under a scenario of technological innovation

1019 for a typical actor (X) and an actor with the ability to build access roads (Y). Innovation
1020 increases the economic rent for all, shifting the bid rent curve up and bringing the frontier
1021 from f to f' , but Y's ability to improve access at the margin changes the angle of her rent
1022 curve, shifting the frontier to f'' and creating a space of "differential rents" dF , where land
1023 investments (i) are profitable only to her. E: Stages of frontier succession. After an abnormal
1024 rent is created, investments flow to the region, leading to an increase in agricultural area and
1025 bid rent. As the bid rent catches up with the economic rent, the abnormal rent disappears,
1026 causing a slowdown in agricultural expansion. Note that while a steep increase in economic
1027 rent is represented here for simplicity, the curve can take more complex forms, such as a
1028 stepwise increase.

1029 Figure 3: Rents, Actors and frontiers. The development of commodity frontiers is a function
1030 of factors creating rents, and of the characteristics of actors that enable them to capture these
1031 rents.

1032 Figure 4: Frontiers of the Gran Chaco. A: Forest cover and deforestation rates for 10-km
1033 radius hexagons; B: Dominant land use at the end of the period; C: Active frontiers, i.e., areas
1034 with high to medium deforestation rates and forest cover, differentiated based on the
1035 geographic origin of their expansion. Data from (Baumann et al. 2016)).

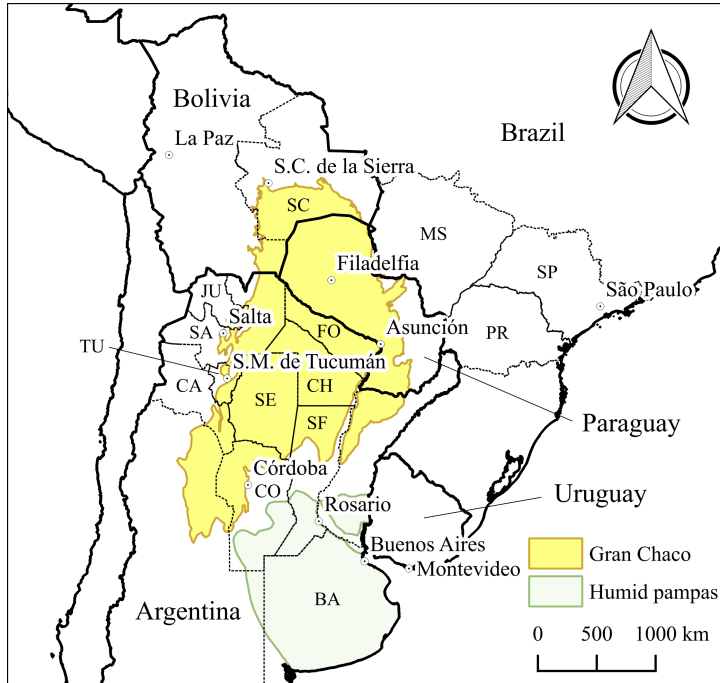
1036 Figure 5: Evolution of land uses (in percent, left axis) and average land prices (in thousand
1037 US dollars, right axis) in each active frontier. Land use proportions are from (Baumann et al.
1038 2016), and land prices from (le Polain de Waroux, Garrett, Heilmayr, and Lambin 2016). We
1039 delineated frontiers manually on the map of frontier areas (Figure 4C), based on contiguity
1040 and direction of expansion.

1041

1042 **Figures**

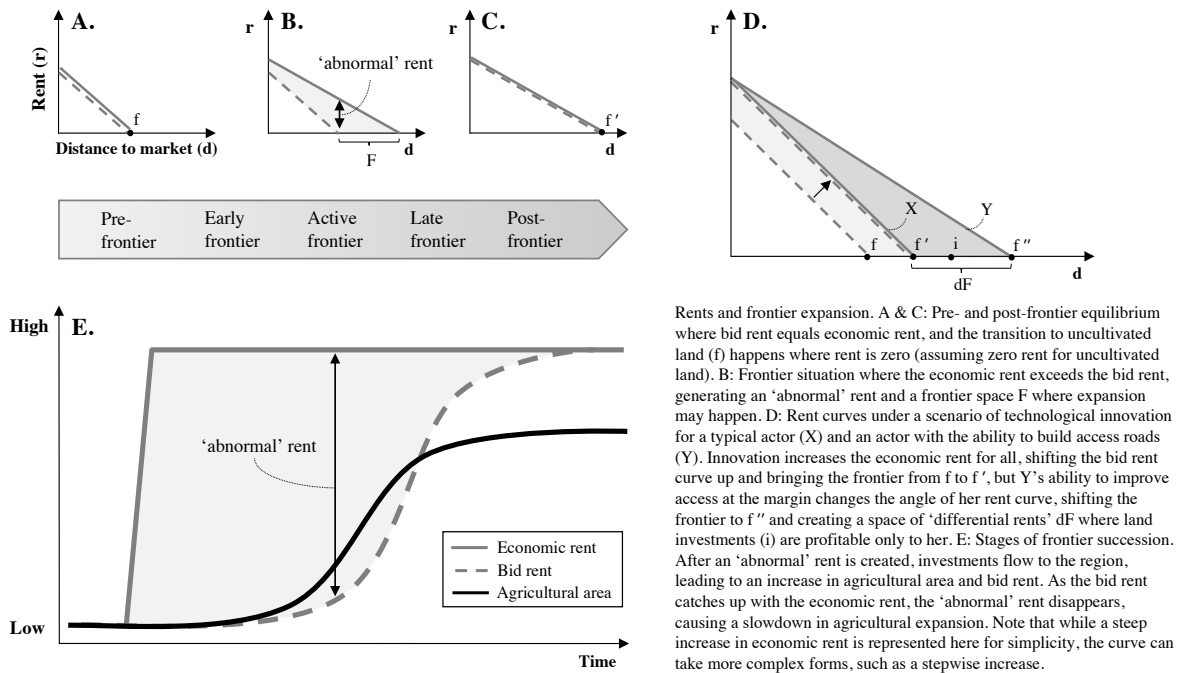
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1044 **Figure 1**



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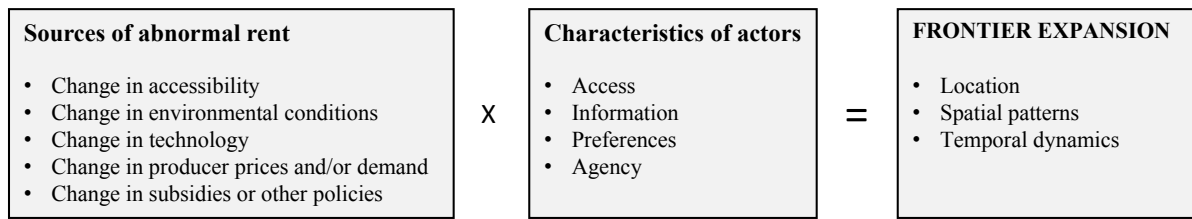
1046 **Figure 2**



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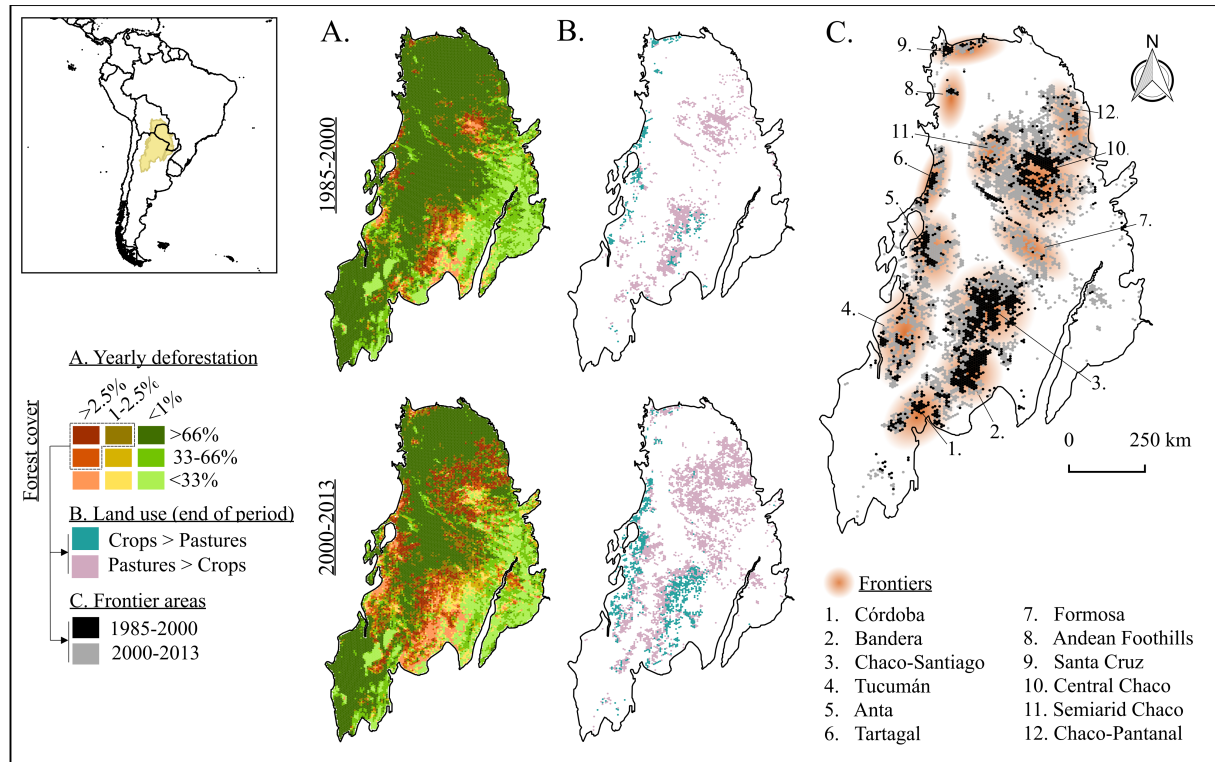
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1049 **Figure 3**



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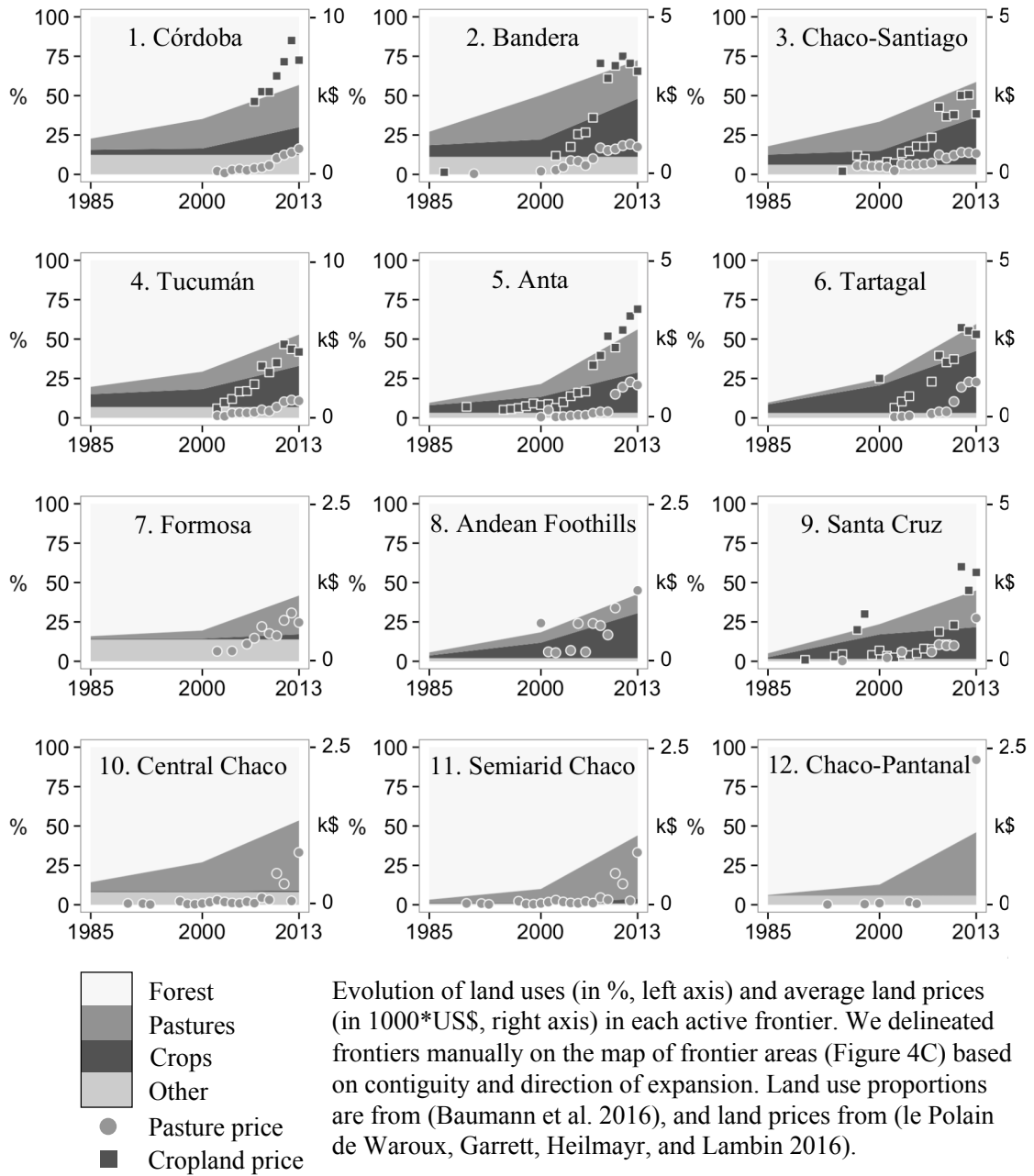
1051 **Figure 4**



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1054 **Figure 5**



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1058 **Tables**

1059 **Table 1**

	Argentina		Bolivia		Paraguay	
	#	Affiliations of interviewees	#	Affiliations of interviewees	#	Affiliations of interviewees
Agricultural producers*	46	n.a.	37	n.a.	43	n.a.
Agricultural cooperatives and lobbies	9	Asociación Argentina de Grupos CREA (AACREA), Asociación Argentina de Productores en Siembra Directa (AAPRESID), Grupo Lajitas, PROGRAMA, Sociedad Rural Argentina (SRA)	10	Asociación Boliviana de grupos CREA (ABCREA), Asociación de Productores de Oleaginosas y trigo (ANAPO), Federación de Ganaderos de Santa Cruz (FEGASACRUZ), UNISOYA, Cámara de Exportadores (CADEX), Instituto Boliviano de Comercio Exterior (IBCE)	10	Asociación de Grupos CREA de Paraguay, Cooperativa Chortitzer, Cooperativa Fernheim, Cooperativa Neuland
Industry and services*	8	Bunge, Cargill	3	ADM-SAO, Asociación de Proveedores de Insumos Agropecuarios (APIA)	6	n.a.
Research and extension services	16	Instituto Nacional de Tecnología Agropecuaria (INTA), Universidad Nacional de Córdoba, Universidad Nacional del Noroeste, Universidad Nacional de Salta	4	Centro de Investigación Agrícola Tropical (CIAT), Universidad Autónoma Gabriel René Moreno	2	Universidad Nacional de Asunción
Social and environmental NGOs	3	Fundapaz, Movimiento Campesino de Santiago del Estero (MOCASE), Proyungas, Red Agroforestal Chaco Argentina (REDAF)	14	Centro de Estudios Jurídicos e Investigación Social (CEJIS), Centro de Investigación y Promoción del Campesinado (CIPCA), Fundación Amigos de la Naturaleza (FAN), Fundación Natura, Fundación para la Conservación del Bosque Chiquitano, Fundación Tierra, Museo de Historia Natural Noel Kempff Mercado, PROBOMA, Sociedad Boliviana de Derecho Ambiental (SBDA), World Wildlife Fund (WWF)	12	Asociación de Servicios de Cooperación Indígena - Menmonita, (ACSIM), BASE Investigaciones Sociales, Fundación Moises Bertoni, Fundación DesdelChaco, Guaya Paraguay, Instituto de Derecho y Economía Ambiental (IDEA), Red Paraguaya de Conservación en Tierras Privadas, Wildlife Conservation Society (WCS) World Wildlife Fund (WWF)
Government organizations	3	Dirección de Bosques de la provincia del Chaco, Dirección de Bosques de la provincia de Santiago del Estero	3	Autoridad de Fiscalización y Control de Bosques y Tierras (ABT), Servicio Nacional de Áreas Protegidas (SERNAP)	7	Instituto Forestal Nacional (INFONA), Municipalidad de Filadelfia, Gobernación de Boquerón, Secretaría del Ambiente (SEAM), Servicio Nacional de Calidad y Salud Animal (SENACSA)

*) Agricultural producers and small-scale services companies are not named for privacy reasons; producers who also have industry and/or services activities are counted only once as producers

1060

1061 **Table 2**

		ARGENTINA							
	Description	Period	1. Córdoba	2. Bandera	3. Chaco-Santiago	4. Tucumán	5. Anta	6. Tartagal	7. Formosa
Size of the active frontier	The total area (in Mha) of active frontier (area of land described as "active frontier" in Figure 4C.)	1985-2000	0.8	1.3	2.4	0.7	0.5	0.3	0.1
		2000-2013	1.4	1.2	4.1	2.3	1.6	0.7	1.6
Deforestation rate	Area deforested as a percentage of total forest area in the "active frontier" at the beginning of the period	1985-2000	16%	32%	15%	12%	13%	16%	4%
		2000-2013	33%	45%	36%	33%	44%	46%	28%
Drivers of expansion	Changes in pasture (P) and cropland (C) area as a % of total deforested area in active frontier	1985-2000	93% P. — 7% C.	84% P. — 16% C.	85% P. — 15% C.	66% P. — 34% C.	56% P. — 44% C.	19% P. — 81% C.	99% P. — 1% C.
		2000-2013	37% P. — 63% C.	-17% P. — 117% C.	15% P. — 85% C.	37% P. — 63% C.	55% P. — 45% C.	38% P. — 62% C.	88% P. — 12% C.
Main actors	Principal actors involved directly in the conversion of land to agriculture	1985-2013	Capitalized farmers from the core agricultural areas of Córdoba	Small-scale (1990s) and capitalized medium-scale farmers (2000s) from Santa Fe and Córdoba	Capitalized medium-scale farmers from Buenos Aires, Santa Fe and Córdoba	Capitalized farmers from Tucumán linked to sugar cane production	Capitalized large-scale farmers from Salta, Jujuy, Santa Fe and Buenos Aires; some US and EU companies	Capitalized farmers from Salta, Jujuy and Buenos Aires; some US and EU companies	Capitalized farmers from Córdoba, Buenos Aires and Chaco
	Technological innovation	1985-2013	No-till agriculture and genetically modified (GM) roundup-resistant (RR) soy in 1996; storage bags mid-1990s; introduction of new pasture varieties						
Sources of increasing rent	Change in environmental conditions	1985-2013	Gradual increase in rainfall (over the second half of the 20th century)						
	Change in accessibility	1985-2013	Major changes predate the study period						
	Change in producer prices and/or demand	1985-2013	Currency devaluation in 2001; booming world price for soy in late 1990s and mid-2000s						
	Subsidies and other public policies	1985-2013	Repayment in pesos of debts contracted in dollars after 2001 devaluation.						
				Road 34 pavement completed in 2005					
			Roads 5, 16 and 30 paved in the 2000s						
			Road 81 pavement completed in 2009						

		BOLIVIA			PARAGUAY		
	Description	Period	8. Santa Cruz	9. Andean Foothills	10. Central Chaco	11. Semiarid Chaco	12. Chaco-Pantanal
Size of the active frontier	The total area (in Mio) of active frontier (area of land described as "active frontier" in Figure 4C.)	1985-2000	0.3	0.1	2.2	0.4	0.4
		2000-2013	0.5	0.3	4.5	1.7	2.0
Deforestation rate	Area deforested as a percentage of total forest area in the "active frontier" at the beginning of the period	1985-2000	19%	14%	15%	7%	7%
		2000-2013	28%	30%	36%	38%	38%
Drivers of expansion	Changes in pasture (P.) and cropland (C.) area as a % of total deforested area in active frontier	1985-2000	22% P. — 78% C.	36% P. — 64% C.	100% P. — 0% C.	99% P. — 1% C.	100% P. — 0% C.
		2000-2013	79% P. — 21% C.	23% P. — 77% C.	99% P. — 1% C.	93% P. — 7% C.	100% P. — 0% C.
Main actors	Principal actors involved directly in the conversion of land to agriculture	1985-2013	Mennonite colonies; farmers from Santa Cruz; Brazilians farmers from Paraná and Mato Grosso do Sul (1990s); Argentine farmers from Córdoba, BsAs and Salta (2000s)	Farmers from Santa Cruz; Mennonite colonies	Mennonite farmers; foreign investors (Uruguay, Brazil, Chile and others) with Mennonite administrators	Mennonite farmers; capitalized East Paraguayan and Brazilian farmers; Uruguayan and other foreign investors (Argentina, Brazil and others) with Mennonite administrators	Capitalized Brazilian farmers from Mato Grosso do Sul and São Paulo states; Mennonite and East Paraguayan farmers and investors (2000s); Uruguayan investors with Mennonite administrators, and some Argentine companies (late 2000s)
		1985-2013	No-till agriculture (>1996) and GM RR soy (legalized in 2005, but introduced illegally before); new pasture varieties (e.g., <i>Panicum maximum</i> , late 1980s)		New pasture varieties (e.g., <i>Panicum maximum</i> in the mid-1980s; <i>Tanzania & Bracchiaria</i> in the 2000s); genetic improvements in cattle; new deforestation techniques; new water harvesting and storage techniques		
Sources of increasing rent	Technological innovation	1985-2013			No change in rainfall has been documented		
		1985-2013					
	Change in accessibility	1985-2013	Improvement of road network by government (1986-91) and under Eastern Lowlands project (1989-1996); Road 4 to Brazil paved late 2000s	Road Santa Cruz-Tarija (paved early 2000s); grid of dirt roads left by previous petroleum exploration	Trans-chaco highway pavement completed in 2008; New all-weather roads throughout the Chaco, built by Mennonites and other investors		
		1985-2013	Currency devaluation & removal of price controls in 1985; Increase in demand for soy following opening of CAN free trade zone in 1992; booming world prices for soy after 2006		Sharp increase in prices due to increased exports following improvement in sanitary conditions (eradication of foot-and-mouth disease in 2005).		
	Subsidies and other public policies	1985-2013	[Currency devaluation in 1985]; suppression of export taxes and reduced tariffs after 1985; cheap loans for agriculture in the 1980's			None	