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Global-local interactions in agrochemical industry: Relating trade regulations in Brazil to environmental and spatial restructuring in China

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ABSTRACT

China and Brazil are the world's leading exporter and importer of agrochemicals respectively. We combine quantitative and qualitative methods to analyze global-local interactions in the spatial restructuring of China's agrochemical industry in relation to a 2006 agrochemical import-acceleration policy in Brazil. We synthesize global political ecology and evolutionary economic geography (EEG) research on environmental regulations, technological upgrading, and the spatial transformations of China's pollution-intensive industries, discussing arguments that the Pollution Haven Hypothesis (PHH) and Porter Hypothesis (PH) co-exist due to firm heterogeneity. While existing studies conceptualize heterogeneity in terms of firm size, regional hub (cluster) effect, and local government intervention, this study adds global-local interactions as dimension of firm heterogeneity – distinguishing firms with weak and strong international linkages. We show the import-acceleration policy in Brazil contributed to the de-concentration of agrochemical production towards western China (confirming the PHH). Yet increasingly strict environmental regulations in China curtailed de-concentration after 2010, when well-established firms and new entrants with strong international linkages consolidated exports to Brazil, while new firms with weaker international linkages exited this market (confirming the PH). This co-existence of PHH and PH due to firm-level heterogeneity of global-local interactions illustrates a theoretical synthesis we call an evolutionary political economic geography (EPEG).

1. Introduction

In this paper we examine the relationship between streamlining environmental regulations for the import of new agrochemical products in Brazil, and the growth, upgrading, and spatial restructuring of the agrochemical industry in China, which has faced increasingly more rigorous environmental regulations in recent years. To do so, we build upon theories of economic geography and employ both qualitative and quantitative methods to examine the following questions: How has the growing and shifting demand for agrochemicals in Brazil articulated with environmental regulations in China? What kind of Chinese agrochemical firms are able to capitalize on the growth and transformation of the Brazilian market to increase exports and upgrade production, and which become unable to cope with these new conditions and must relocate or exit this market instead? Applied geographical analysis of these empirical questions enables us to synthesize global political ecology and evolutionary economic geography (EEG) research on environmental regulations and technological upgrading, illustrating what we call an evolutionary *political economic* geography (EPEG) approach. Our empirical findings and theoretical analysis demonstrates co-existence of the Pollution Haven Hypothesis (PHH) and Porter Hypothesis (PH) due to firm heterogeneity in terms of global-local interactions – in particular, how a transformation in global agrochemical markets and an international shift in environmental and trade policy articulates with the trajectory of firms differentiated by their international linkages and distinct environmental regulations at the local level.

We first provide an empirical background and motivation for our research, and describe the theoretical debates with which we engage. Then we formulate three hypotheses to answer our research questions. We then describe our data and methods, and employ quantitative analysis to test those hypotheses, and qualitative examination of case studies that deepen our discussion of firm-level heterogeneity. We conclude with acknowledgement of the limitations of this paper, policy recommendations, and observations for further research.

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2. Empirical background and motivation

Agrochemicals[1] compose a significant and fast growing segment of international trade. In 2000, the international market for agrochemicals was about 10.5 billion USD (Comtrade, 2019).[2] China was the 6th largest exporter, supplying about 463 million USD (about 4.4% of total exports). However, this share was dwarfed by Germany, France, US, UK, and Switzerland, which together accounted for over 60% of total agrochemical exports. At that time, Brazil was the 11th largest importer, receiving 260 million USD of agrochemicals from abroad (about 2.5% of international trade). The ten largest importers were all countries in western Europe, alongside the US and Japan. By 2017, the global geography of agrochemical production and trade was radically transformed. International trade more than trebled to 34.3 billion USD, and de-concentrated from western Europe, the US, and Japan to various developing countries. China became the largest exporter, selling about 4.7 billion USD (about 13.7% of all exports), while Brazil became the largest importer, purchasing about 2.5 billion USD (about 7.3% of this international market). Evidently, Chinese exports to Brazil account for the main flow that restructured global agrochemical markets. After all, Chinese agrochemical exports to Brazil increased almost tenfold from merely 31.7 million USD in 2000 to 307 million USD in 2017, the sharpest increase in bilateral trade witnessed in this sector. Although we cannot attribute the expansion and spatial restructuring of China's agrochemical industry to shifts in its international linkages alone, it is reasonable to presume that the growth and transformations of the Brazilian demand for agrochemical imports is one of the principal external factors influencing this process.

Evidently, China's emergence as the "world's factory" and Brazil's simultaneous emergence as the "world's granary" are connected not only through the widely recognized expansion of Brazilian agricultural exports to China (Oliveira, 2018; Oliveira & Schneider, 2016), but also by the growing exports of Chinese agrochemicals to Brazil. Yet this latter aspect remains underexplored, and there are no studies yet of its geographical expression within China. Moreover, chemical production and agrochemical use are responsible for some of the most serious incidents of environmental pollution and intoxication worldwide (Bombardi, 2013, 2017; Cao et al., 2018; Duan, Chen, Ye, & Chen, 2011; Pelaez, Terra, & Silva, 2010). Thus, environmental regulations on production, imports, and use are key factors determining the global geography of the agrochemical industry.

These concerns cannot be underemphasized, as the production and transportation of hazardous chemicals accounts for about half of all environmental incidents in China, causing hundreds of deaths and thousands of fatalities each year (Cao et al., 2018; Duan et al., 2011). In 2018, the Chinese central government reported that 1176 chemical enterprises were at risk of major hazards, so 479 of them must be relocated, 360 need to be upgraded, and 337 are ordered to be shut down (Wang, 2019). Meanwhile in Brazil, over 87 thousand cases of intoxication by agrochemicals were reported between 1999 and 2014, causing the death of at least 3062 individuals (Bombardi, 2013, 2017). As Brazil loosens regulations to increase agrochemical imports, and China pushes for the spatial and technological restructuring of its agrochemical industry, applied geographical analysis is crucial to comprehend how these complex global-local interactions are transforming the agrochemical industry in China and around the world.

[1] These include insecticides, fungicides, and nematicides, collectively known as pesticides, as well as herbicides, synthetic fertilizers, hormones, and other growth agents. In this paper, we only examine pesticides and herbicides, to which we refer collectively as "agrochemicals".

[2] All data in this paragraph derived from UN Comtrade (2019).

3. Theory

Our research engages theoretical debates about the relationship between environmental regulations and industrial dynamics, in particular the dispute regarding the Pollution Haven Hypothesis (PHH) and the Porter Hypothesis (PH). The PHH argues that uneven environmental regulations between regions induces the relocation of pollution-intensive industries to regions with lax regulations and implementation (Copeland & Taylor, 2004; Dean, Lovely, & Wang, 2009), causing disinvestment in the sector due to increased costs of compliance with environmental regulations, and a "race to the bottom" among local governments attempting to attract pollution-intensive industries (Wheeler et al., 1999; Shen, Wei, & Yang, 2017). The PH, on the other hand, argues environmental regulations induce technological upgrading to offset compliance costs and innovations to generate new competitive advantages (Kumar & Managi, 2009; Porter & van der Linde, 1995), triggering instead a "race to the top" among regions and firms seeking to gain market shares in new institutional circumstances (Li & Fung Research Centre, 2008; Zhu & Pickles, 2014).

Most studies seek to apply or verify either PH or PHH independently, neglecting or implicitly negating the other hypothesis, but the theoretical validity and practical applications of both hypotheses have suffered from the fact that empirical evidence for each competing theory has been mixed and inconclusive (Dam & Scholtens, 2008; Jeppesen & Folmer, 2014; Tole & Koop, 2011). Theoretical breakthroughs have occurred primarily through recent geographical studies that show how the impact of regulations is shaped by firm-level (rather than industry- or regional-level) characteristics and capabilities (Lin, Wang, Zhou, Sun, & Wei, 2011; Martin, 2010; Wang, Lin, & Li, 2010), and consequently the PH and PHH can *co-exist* due to firm heterogeneity (Zhou, Zhu, & He, 2017; Zhu, He, & Liu, 2014). In this paper, we build upon this theoretical insight providing further empirical evidence of the co-existence of the PH and PHH in the national-level restructuring of China's agrochemical industry. Although this verification is partial due to our empirical focus on Chinese agrochemical exporters to Brazil, this more nuanced scope also allows us to develop this new theoretical approach in an important new direction, theorizing global-local interactions as a relevant dimension of firm heterogeneity.

So far, the literature attributes the variation and/or co-existence of the PH and PHH to firm size and capabilities, understood as endogenous characteristics of financial and technological capacity or ownership structure, alongside the regional hub (cluster) effect and variations in government intervention at the local level (Shi & Xu, 2018; Wu, Guo, Zhang, & Bu, 2017; Zhou et al., 2017; Zhu et al., 2014). Missing from this literature is examination of firm heterogeneity in terms of exogenous characteristics, such as variations in the number of products exported and number of international destinations by country (cf. Koenig, Mayneris, & Poncet, 2010). Yet there is also a growing body of literature that demonstrates the need to examine the global-local interactions that conjoin endogenous factors (like firm size and local subsidies for technological upgrading) alongside exogenous factors (such as shifts in international market demand and regulations) in restructuring industrial production and trade (Lin, Moon, & Yin, 2014; Yang, 2012; Yasar & Paul, 2007). Thus, our theoretical contribution emerges from our finding that firms facing simultaneous shifts in environmental regulations and international trade may be affected by conflicting trends of spatial de-concentration and re-concentration due to global-local interactions.

Our discussion of global-local interactions as an essential factor for analysis of regional economic transformations associated with environmental governance synthesizes theoretical insights from two strands of our previous work. First, our scholarship in evolutionary economic geography (EEG), global value chains, and global production networks in the Global South has revealed that processes of technological "upgrading" and "strategic coupling" between local actors and counterparts in the global economy (Coe, 2012) must be understood as embedded within a heterogeneous framework of local and national governance (He & Zhu, 2019). This strand of our work has defied simplistic accounts of environmental Kuznets curves in the Global South, demonstrating, for example, that "export upgrading can, but does not necessarily, lead to environmental improvement" (Mao & He, 2017, p. 150; Zhu et al., 2014; Zhou et al., 2017). This insight dovetails with our second strand of research in global political ecology (Peet, Robbins, & Watts, 2011), which similarly challenges linear accounts of environmental modernization, as we have shown elsewhere in the context of the soy, livestock, and biofuel industries in Brazil, China, the US, and the EU (Oliveira, McKay, & Plank, 2017; Oliveira & Hecht, 2016; Oliveira & Schneider, 2016). Thus, our present synthesis reinforces arguments that the expansion of South-South economic relations has transformed not only the patterns of trade, investment, and environmental governance, but also generated conditions to "theorize back" at mainstream economic geography from the point of view of the Global South (Horner, 2016; Horner & Nadvi, 2018; Yeung, 2007; Zhu & He, 2019).

We argue that heterogeneity in the *international linkages* of firms (independently of firm size) contributes to whether a firm is able to seize upon shifts in international markets to generate new competitive advantages and invest in the technological upgrading required to offset environmental compliance costs (illustrating the PH), or whether a firm fails to do so and must either exit this new market or relocate to regions with weaker environmental regulations (illustrating the PHH). As we combine approaches from both EEG and global political ecology, our theoretical synthesis may be termed an evolutionary *political economic* geography (EPEG), which enables global-local interactions in environmental governance to be examined as the crux of complex transformations in regional development and industrial production (Fig. 1). We develop this theoretical synthesis of EPEG by examining the interconnection between a shift in Brazilian agrochemical markets and import regulations, with transformations in environmental protection and technological upgrading of the agrochemical industry in China. Moreover, EPEG combines the quantitative analysis of EEG, which relies upon proxy measures that can indicate correlations and possible explanations of firm behavior, with the qualitative approach of political ecology, enabling us to verify whether the proxy measures employed and correlations identified actually reflect causal connections and valid explanations of firm behavior in concrete case studies.

4. Research hypotheses

The dramatic expansion of Brazilian agrochemical imports results not simply from the growth of its agricultural production sector and ecological conditions,[3] but from more specific political and institutional transformations. A relatively robust agrochemical industry had developed there during the mid-20th century through import-substitution industrialization, but stricter health and environmental regulations, alongside neoliberal reforms since the 1990s curtailed the growth of the domestic agrochemical industry (Pelaez et al., 2015). Yet demand increased from the growing agricultural sector, which continuously requires new products to compensate for pest and weed resistance to agrochemicals, especially in the extensive monocultures of herbicide-resistant transgenic soy that increased the most since 2000 (Binimelis, Pengue, & Monterroso, 2009). Thus, strict regulations on agrochemical production and trade came into tension with agribusiness and government interests to facilitate agrochemical imports (Pelaez et al., 2010; Silva & Costa, 2012).

In Brazil, agrochemicals must be individually registered with the federal government's environmental and health agencies, who assess their quality and safety risks, prior to receiving approval for production or import by the Ministry of Agriculture (Santos, 2012; Fonseca, 2018).[4] Since the requests for registration of newer and more toxic products far outpace the government's capacity for evaluation, the time it takes for a new product to be approved for production/import increased dramatically. Consequently, the Brazilian government issued a decree in 2006 to expedite the registration of generic (off-patent) agrochemical products with active ingredients considered to be "equivalent" to others already available in Brazilian markets (Fonseca, 2018).[5] The goal was to reduce the time required for registration from about 3-to-4 years to merely 6 months. However, the policy shift also caused a huge influx of new requests for registrations, which increased the backlog awaiting evaluation. Still, this import-acceleration (IA) policy did reduce the average time for registration to 1.5–2 years (Pelaez, da Silva, Guimarães, Dal Ri, & Teodorovicz, 2015). Chinese-made agrochemicals were already flooding the Brazilian market, but this trade was intermediated by the leading companies from the US and Europe, which already held registrations for these products in Brazil.[6] The new IA policy, therefore, facilitated the entrance of new players making direct sales to the Brazilian market, especially Chinese companies that were fast becoming the world's largest exporters of generic pesticides (KPMG, 2013). Therefore, we will attempt to verify the following hypothesis:

H1. The IA policy in Brazil was effective and had a positive effect on Chinese exports.

After all, the composition of agrochemical exports from China to Brazil changed significantly from 2000 to 2016, and the city-level location of the main exporting firms also transformed (Fig. 2). Thus, verification of H1 lays the foundation for subsequent analysis, as it demonstrates that shifts in Brazilian agrochemical regulations are a relevant factor for the study of global-local interactions in China's agrochemical sector. Note, however, that we do not need to argue that China was the sole or even primary beneficiary of Brazil's IA policy, even if UN Comtrade data on the transformation of the global agrochemical market (cited in section 2) and our own interviews (see qualitative analysis below) do suggest as much.

In addition to rising international demand, the dramatic expansion of China's agrochemical industry can be attributed to the usual domestic factors that explain its broader fast-paced export-oriented industrialization (Perlitz, 2005; Feng, 2008). However, a more nuanced historical geography does identify specific characteristics of the sector that are worth highlighting. During the early 2000s, agrochemical production was concentrated around the Yangtze river delta (Shanghai, Jiangsu, and Zhejiang provinces), with a few smaller clusters in Shandong, Hebei, Chongqing, and Guangdong (Fig. 2). Government policy in these regions encouraged the development of this sector through the establishment of specialized chemical industry parks, especially during the slowdown of higher technology industries in the aftermath of the Asian financial crisis of 1997 (Bathelt & Zeng, 2012). This technological upgrading and public investments to facilitate environmental compliance illustrates growth trajectories that verify the PH. On the other hand, as pollution and deadly accidents increased due to the production and transportation of hazardous chemicals, especially in the Yangtze delta and other highly industrialized coastal regions (Cao et al., 2018; Duan et al., 2011), government policy began to encourage the upgrading and/or relocation of the agrochemical industry towards less industrialized areas (Zeng & Bathelt, 2011; Zhu et al., 2014), as witnessed in the maps of firms exporting to Brazil in 2006 and 2010 (Fig. 2). This provides evidence of the PHH, as chemical firms are pushed to exit or relocate to regions with

[3] The absence of snow and cold winters allows pests and weeds to survive year-round, while the prevalence of monocultures promotes pest and weed resistance to agrochemicals.

[4] Law 7.802, enacted in 1989.

[5] Decree 5.981/06.

[6] Chinese pesticides registered for sale in Brazil (through non-Chinese distributors) rose from 60 in 2000 to 117 in 2006, while Brazilian products decreased over the same period from 242 to 235 (Macauhub, 2007; Valor, 2007).

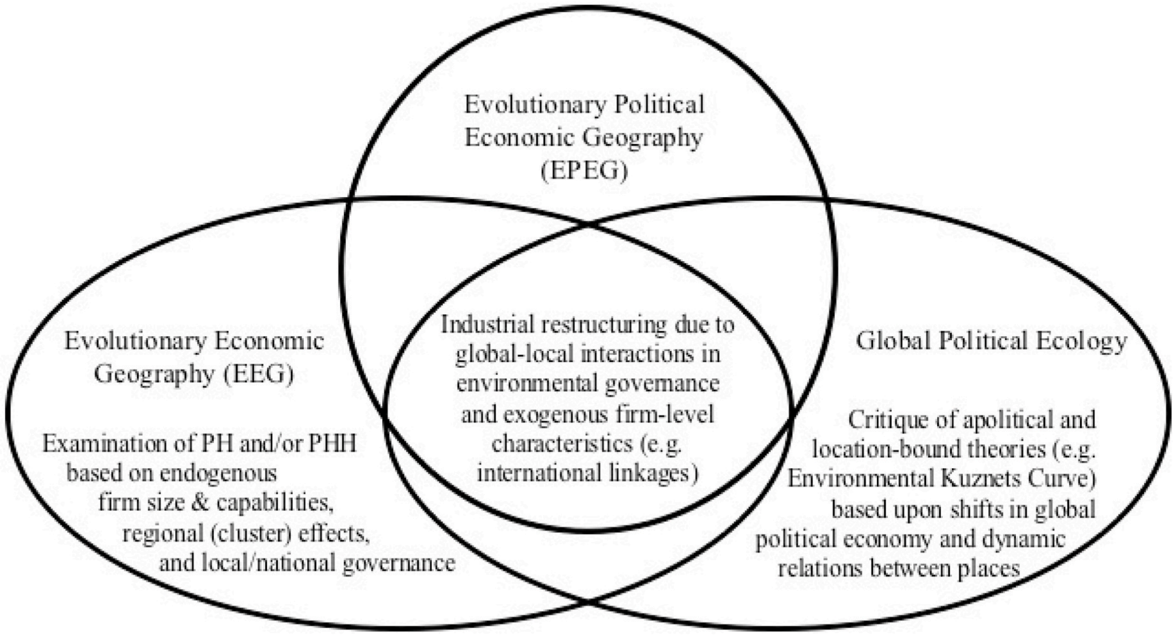

Fig. 1. Evolutionary Political Economic Geography.
Source: Elaborated by the authors.

less strict environmental regulations.

Recent studies that test the PH and PHH in China's pollution-intensive industries suggest variations in local institutional conditions are statistically significant determinant factors of differentiated outcomes (Zhu et al., 2014; Zhou et al., 2017; Shen et al., 2017). In order to analyze this co-existence of the PH and PHH, therefore, we must first examine the relative location and strength of factors pushing exit/relocation vs. inducing innovations/upgrading among firms exporting agrochemicals to Brazil. Thus, we will examine the following hypothesis:

H2. Firms in regions with increasingly stringent environmental regulations are more likely to relocate or exit, despite new markets opened by the Brazilian import-acceleration policy.

The verification of H2 suggests that the forces of de-concentration that undergird the PHH are effective with regards to China's agrochemical industry. We can also measure the possibility that environmental regulations might have efficiency-promoting effects in certain regions, increasing the likelihood that a firm would maintain or increase exports to Brazil as its IA policy encourages production and exports of new generation products, thus verifying the PH instead.

Finally, in order to advance the theorization that variation and co-existence of PH and PHH results not only from regional differences, but also from firm-level heterogeneity, we must develop a measurement of firm heterogeneity that can capture the global-local interactions relevant for our present analysis. Our previous qualitative research of Chinese agrochemical firms expanding to the Brazilian market indicates that most Chinese firms successfully registering products for direct exports to Brazil rely upon international partners for information and Brazilian consultants to succeed in this bureaucracy-intensive process.[7] Additional research has shown that international linkages of Chinese firms affects their environmental compliance and performance (Lin et al., 2014), which might also enable them to upgrade production to maintain or expand exports to Brazilian markets after the implementation of the IA policy. Therefore, we propose that firms with more *international linkages*, measured by number of products exported and number of international destinations by country (as in Koenig et al., 2010), may be more capable to seize the opportunity of Brazil's IA policy (regardless of their size and ownership structure). Thus, we will test this third hypothesis:

H3. Firms with more international linkages are more likely to upgrade and enter the Brazilian market, while firms with less linkages are more likely to exit this market.

Verification of H3 can explain how and why the PHH might induce de-concentration of the sector among certain firms, while the PH simultaneously induces the re-concentration among other firms, due to the specific global-local interactions that characterize each of them. Ultimately, this would demonstrate that exogenous firm characteristics, such as their international linkages, are relevant factors (alongside endogenous firm characteristics, cluster effects, and local government intervention) explaining the co-existence of PH and PHH.

5. Data and research methods

We utilized the UN International Trade Statistics Database (Comtrade) for description of the overall Chinese, Brazilian, and international agrochemical market, and both city-level and firm-level Chinese customs data for quantitative analysis of Chinese agrochemical exports to Brazil. To specify agrochemicals in the custom data, we selected 8-digit HS codes for all items identified in the *List of Import and Export Agricultural Chemicals*, jointly announced by the Chinese Ministry of Agriculture and Rural Affairs and General Administration of Customs. These included both pesticides and herbicides as final products for retail/wholesale ("formulated products"), as well as the precursor chemicals that serve as active ingredients for the formulation of pesticides and herbicides ("technical products"). Data on pollution incidents and investments in anti-industrial pollution projects are obtained from the annual reports of the National Bureau of Statistics of China (NBS). We employ difference-in-differences (DD) and Probit models for statistical analysis. For the Probit models, we draw upon NBS data for all control variables, including city- and province-level GDP, foreign direct

[7] Personal interviews by first author with three Chinese executives of agrochemical firms, two US intermediaries registering Chinese agrochemicals in Brazil, and three Brazilian consultants working with Chinese agrochemical companies as clients, Beijing, São Paulo, and Rio Grande do Sul, 2014–2015.

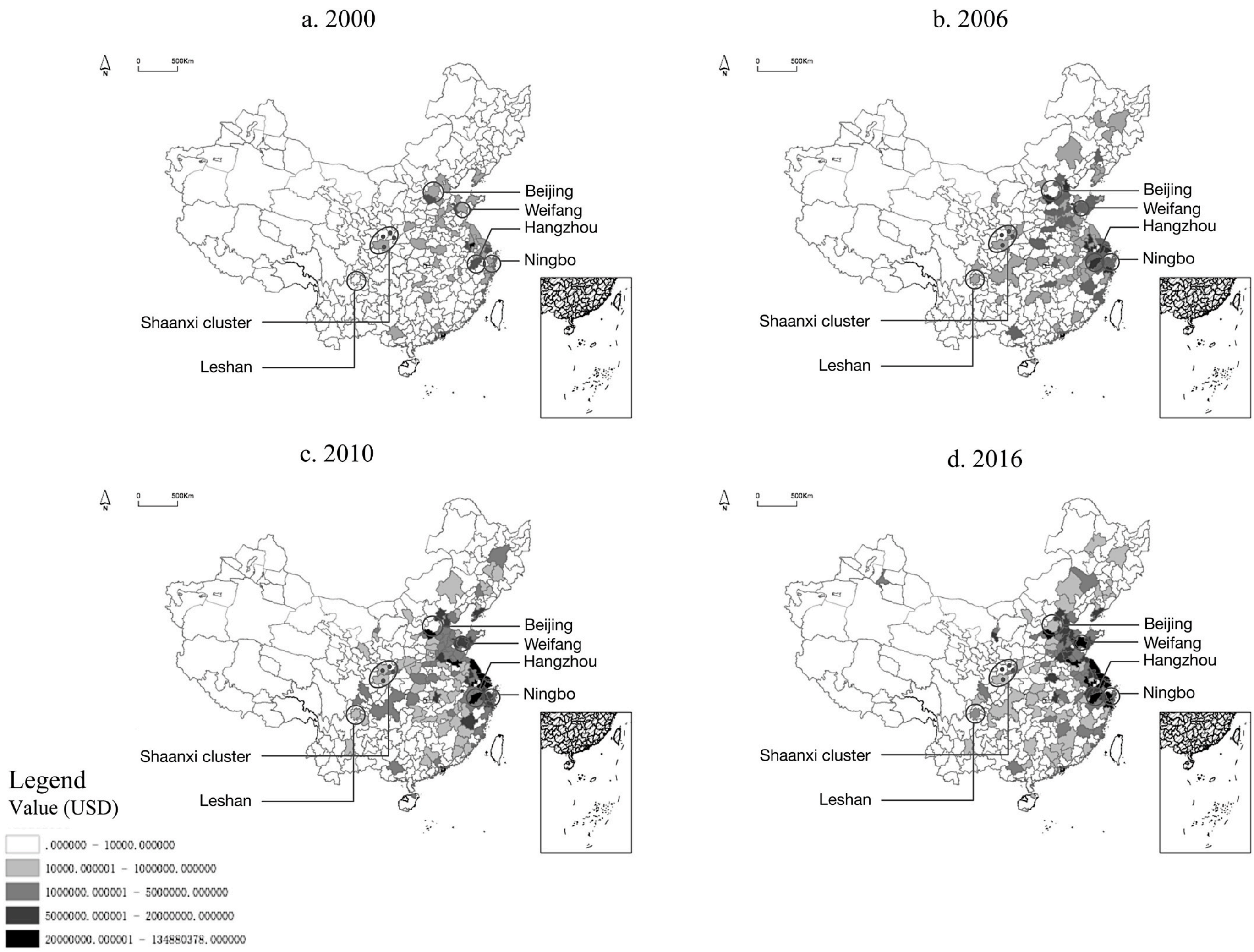

Fig. 2. City-level agrochemical exports to Brazil (RMB): 2000, 2006, 2010, and 2016
Source: Elaborated by the authors from Chinese customs data.

Table 1
DD results for agrochemical and other chemical exports from China to Brazil (2000–2016).

	(1)value	(2)value	(3)value
Treat	23082.4*** (2.89)		
Post2008	271401.9*** (21.07)		
Treat*Post2008	135475.1*** (4.23)	155674.7*** (5.29)	167220.5*** (5.32)
Time FE	No	Yes	Yes
Province FE	No	Yes	No
_cons	116518.7*** (21.32)	238676.1*** (2.94)	89653.5*** (8.25)
N	62822	62822	62822

t statistics in parentheses.
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 2
DD results for agrochemical exports from China to Brazil and Argentina (2000–2016).

	(1)value	(3)value	(4)value
Treat	−26626.9 (-1.44)		
Post2008	189464.4*** (5.78)		
Treat*Post2008	217412.6*** (4.95)	195982.4*** (4.92)	189277.5*** (4.78)
Time FE	No	Yes	Yes
Province FE	No	Yes	No
_cons	166228.0*** (9.49)	−95132.7* (-1.87)	170925.6*** (3.70)
N	37810	37810	37810

t statistics in parentheses.
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

investment (FDI), number of foreign-owned enterprises, and average wages in manufacturing industries.

Descriptive and qualitative analysis of Brazilian agrochemical regulations and registration for imports draws upon Brazilian government records, including the relevant legislation and the databases of the Brazilian government's National Sanitary Surveillance Agency (Agência Nacional de Vigilância Sanitária – ANVISA) and Ministry of Agriculture, Livestock, and Supply (MAPA). Qualitative analysis of the behavior of agrochemical companies draws upon personal interviews undertaken by the first author in both China and Brazil between 2011 and 2019. These included Chinese company executives, and their Brazilian partners and consultants working directly on the registration of Chinese agrochemicals for export to the Brazilian market. Company information and public statements by executives found in company websites, the media, and sector-specific forums were used to supplement these materials.

6. Quantitative analysis

We applied difference-in-difference (DD) methods to test the first hypothesis. First, we compared Chinese exports of agrochemicals (treatment group) to exports of other chemical products (control group) to Brazil, as the latter were not included in the IA policy. Second, we used another set of treatment and control group data as a robustness test, comparing agricultural chemical exports to Brazil (treatment group) and to Argentina (control group). Chinese agrochemical exports to Argentina provide a suitable control, since the agroindustrial sector of both countries is very similar, particularly regarding soy production, which accounts for the largest share of agrochemicals consumed in both countries (Santos, 2012; Pelaez et al., 2015), yet Argentina did not implement a similar IA policy. We examine Chinese customs data from 2000 to 2016, setting 2008 as the turning point for statistical analysis, when the effect of Brazil's IA policy began to appear in international trade. This is because it took about 1.5–2 years after the implementation of the IA policy in 2006 for the first new set of products registrations to be approved under this new regulatory regime.

In both cases, we employ the following equation

$$Export_{i,t} = \alpha_0 + \alpha_1\ treat + \alpha_2\ post2008 + \alpha_3 \cdot treat{*}post2008 + \varepsilon_{i,t}$$

in which, ***treat*** is a dummy variable for treatment group or control group. We assign *treat* = 1 if the observation is in treatment group, otherwise, *treat* = 0; *post2008* = 1 if year>2008, otherwise, *post2008* = 0. In this equation, $\alpha_3 \cdot$ is the key estimator we focus on, which represents the effect of Brazil's IA policy on agrochemical exports. Results for the DD comparison between agrochemical and other chemical exports to Brazil are displayed in Table 1, and results for the DD comparison between Brazil and Argentina are displayed in Table 2.

In both tests, the DD estimators are significant, proving our first hypothesis that the IA policy was effective. This demonstrates that Brazil's IA policy is relevant for analysis of global-local interactions in the upgrading and spatial restructuring of China's agrochemical sector. The DD comparison between agrochemical and other chemical exports

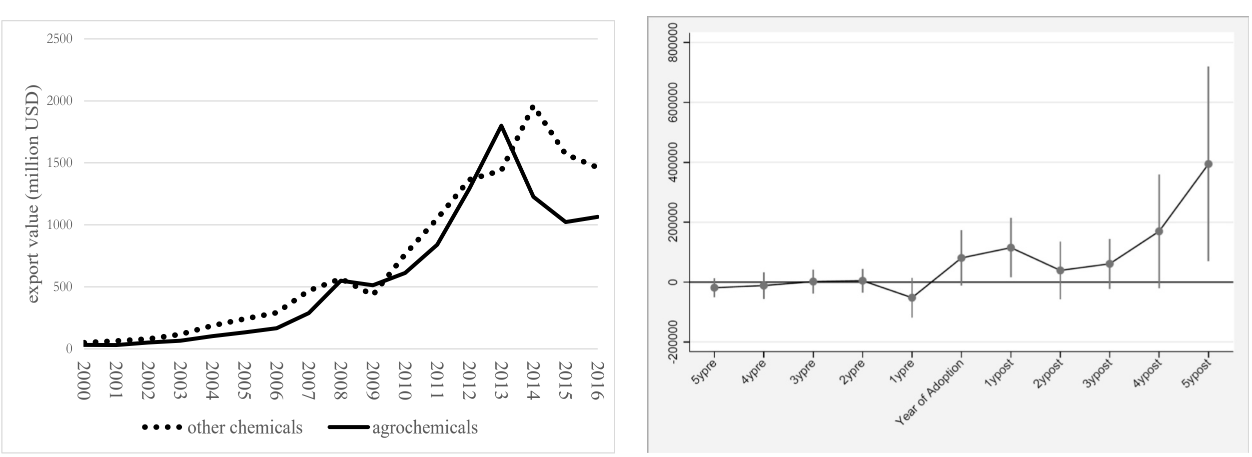

Fig. 3. DD between agrochemical and other chemical exports to Brazil (2000–2016) and common trend assumption test.
Source: Elaborated by the authors from UN Comtrade.

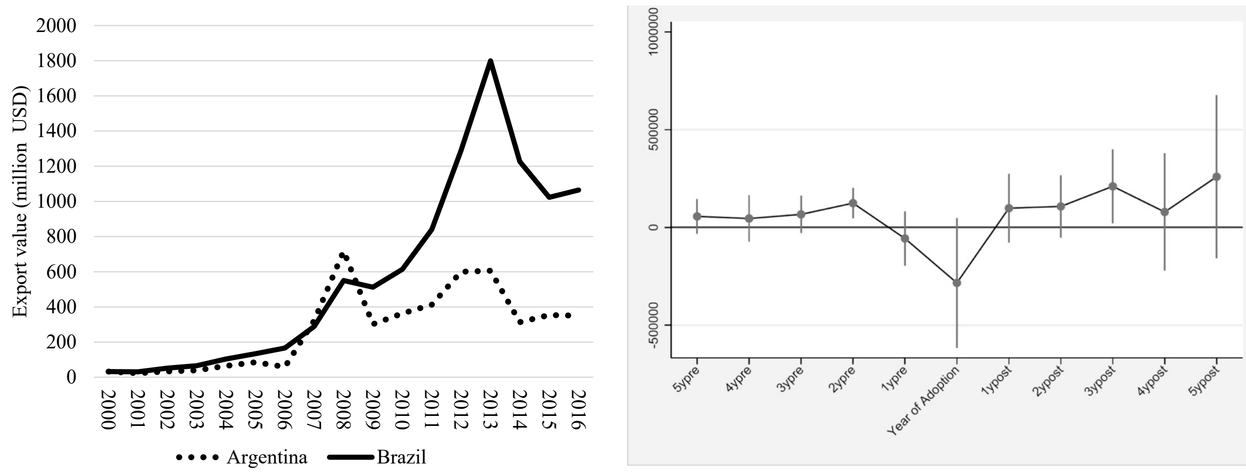

Fig. 4. DD between agrochemical exports to Brazil and Argentina (2000–2016) and common trend assumption test.
Source: Elaborated by the authors from UN Comtrade.

to Brazil passes the common trend assumption test with very strong results (Fig. 3). It is particularly clear how the IA policy enabled a far sharper rise of agrochemical exports to Brazil when compared with Argentina, even despite an overall reduction in agrochemical exports to both countries after 2013, when agricultural commodity prices fell and both countries entered recession (Fig. 4).

To test the second hypothesis, we employ a Probit model to measure the effect of increasing environmental regulations on the likelihood that firms would relocate, reduce exports, or exit the Brazilian export market (verifying the PHH). We also measure the possibility that environmental regulations might have efficiency-promoting effects, increasing the likelihood that a firm would maintain or increase exports to Brazil as its IA policy encourages production and exports of new generation products (verifying the PH instead). NBS data on public expenditures on anti-pollution projects (measured in renminbi) is used as proxy for increasingly stringent environmental regulations, including efficiency-promoting production protocols, and NBS data on environmental pollution incidents is used as proxy for a local political environment that encourages strict enforcement in its aftermath.

We define firm entry, exit and maintaining as follows. If firm *i* is not included in the dataset in year *t*-1 but in year *t*, it is assumed that in year *t* firm *i* enters. If firm *i* is included in the dataset in year *t-1* but not included in year *t*, it is assumed that in year *t* firm *i* exits. Similarly, if firm *i* is included in the dataset in year *t-1* and continues to be included in year *t*, it is assumed that in year *t* firm *i* maintains its export activities. We use local investment (*lninv*) on environment, and incidents of environmental accidents or incidents (*lnacc*), to represent the effort of local environmental protection. This is because enforcement tends to increase in the aftermath of environmental incidents (cf. Cao et al., 2018; Duan et al., 2011). In the model, we included multiple city and province level control variables. We include city GDP and province level GDP per capita in year *t* (*lncgdp* and *lnprovpgdp*). The openness of the province is measured by FDI level (*lnfdi*) and number of foreign-owned enterprises (*lnfoe*). The development of local manufacturing industries is measured through average wage of manufacturing industry (*lnwage*).

At the national level, the model shows statistically significant positive results for increasing environmental regulations and firm entry, exit, and maintenance of the Brazilian export market during the whole period from 2000 to 2016 (Table 3a). This undifferentiated correlation with firm entry, exit, and maintenance of exports to Brazil indicates that transformations in import regulations contributed to a *more dynamic* environment for China's agrochemical industry. We interpret this as an economic environment that encourages some firms to experiment with new products to access this new/growing Brazilian market (illustrating the dynamics of the PH), but also encourages other firms to exit Brazilian exports by experimenting with alternative markets for earlier-generation products, as those become replaced by new competitors (which illustrates a version of the PHH regarding export-destination rather than site of production, and suggests the PHH might also be in effect through production shifting outside of China). In all, this result indicates co-existence of the PH and PHH for agrochemical production in China at the national level.

Nationwide model results also indicate environmental accidents correlate with *fewer* firms exiting Brazilian export markets, which appears to challenge our second hypothesis. This may occur for two reasons. First, the NBS dataset on environmental incidents might over-represent locations where there is more information/transparency about environmental pollution. After all, measurements of the Pollution Information and Transparency (PIT) Index display wide variations across cities and provinces, and greater transparency is correlated with stronger environmental restrictions and more robust efforts to upgrade polluting industries (IPE/NRDC, 2010). Consequently, the nationwide correlation of *reported* environmental incidents with *fewer* firms exiting Brazilian export markets might reflect more clearly the efficiency-upgrading effect of anti-pollution governance initiatives, rather than crackdowns that result in firm exit and relocation beyond China. Or in other words, it might provide further evidence for PH rather than PHH.

Second, since nationwide models might not accurately reflect variations in environmental regulations and production governance across regions in China, we tested our second hypothesis more carefully by examining differences between firms located in eastern, central, and western China. In these regionally-specific models, results are inconclusive for both eastern and central China, which we again interpret as evidence of the simultaneous co-existence of both PH and PHH, but they confirm our second hypothesis in western China (Table 3b).[8] We believe this is explained by the disproportionate concentration of both agrochemical production *and* environmental accidents in the Yangtze river delta (Cao et al., 2018), where the higher incidence of environmental accidents is matched by higher investment in anti-pollution initiatives *and* higher PIT Index (IPE/NRDC, 2010). Moreover, in these regions firms benefit from robust local/provincial government efforts to channel chemical production into specialized industrial parks within the region (Bathelt & Zeng, 2012; Zeng & Bathelt, 2011). That is, local institutional environments in eastern and central China might strengthen factors inducing upgrading (illustrating the PH), which counteract factors pushing relocation to "pollution havens" (as might have been expected

[8] Results for eastern and central China provided in the appendix.

Table 3

a Firm level entry/exit/maintenance of Brazilian export market, nationwide (2000–2016)

	(1)entry	(2)exit	(3)maintain	(4)entry	(5)exit	(6)maintain
lninv	0.0581***	0.0759***	0.159***			
	(3.06)	(3.34)	(5.92)			
lnacc				−0.0164	−0.0240**	−0.0279*
				(-1.17)	(-2.18)	(-1.69)
lncgdp	−0.0374***	−0.0293*	−0.125***	−0.0535**	−0.0506*	−0.170***
	(-3.00)	(-1.88)	(-3.71)	(-2.21)	(-1.81)	(-3.22)
lnfdi	−0.0263	−0.0534	0.00251	−0.00211	−0.0142	0.0712
	(-0.94)	(-1.63)	(0.04)	(-0.07)	(-0.37)	(0.90)
lnwage	0.266***	0.486***	0.106	0.250**	0.453***	0.114
	(2.84)	(5.97)	(0.90)	(2.02)	(4.18)	(0.79)
lnfoe	−0.00873	0.0241	−0.0908	−0.0210	0.00341	−0.104
	(-0.28)	(0.72)	(-1.37)	(-0.67)	(0.09)	(-1.27)
lnprovpgdp	0.0676	−0.0330	0.484***	0.106	0.0246	0.531***
	(0.83)	(-0.45)	(3.58)	(1.06)	(0.27)	(3.36)
_cons	−5.099***	−6.832***	−7.688***	−4.541***	−6.051***	−6.324***
	(-10.09)	(-15.00)	(-13.41)	(-9.36)	(-14.66)	(-9.66)
N	55181	55181	55181	53199	53199	53199

b. Firm level entry/exit/maintenance of Brazilian export market, western China (2000–2016)

	(1)	(2)	(3)	(4)	(5)	(6)
	entry	exit	maintain	entry	exit	maintain
lninv	0.0171	−0.00888	0.127**			
	(0.35)	(-0.15)	(2.03)			
lnacc				−0.00303	0.0423**	0.000629
				(-0.11)	(2.02)	(0.02)
lncgdp	−0.0360*	−0.0286	−0.131***	−0.0519**	−0.0488	−0.137***
	(-1.73)	(-0.74)	(-2.59)	(-2.34)	(-1.06)	(-2.90)
lnfdi	−0.0406	−0.0365	0.115	−0.0503	−0.0265	−0.0236
	(-0.38)	(-0.27)	(0.96)	(-0.60)	(-0.25)	(-0.16)
lnwage	0.387**	0.632***	0.470	0.377**	0.627***	0.554
	(2.18)	(3.05)	(1.49)	(2.04)	(2.90)	(1.62)
lnfoe	0.102	0.168	−0.115	0.0895	0.114	0.0413
	(1.06)	(1.39)	(-1.04)	(1.21)	(1.40)	(0.33)
lnprovpgdp	0.0563	−0.0730	0.0935	0.110	−0.0166	0.149
	(0.52)	(-0.48)	(0.34)	(1.01)	(-0.11)	(0.58)
_cons	−6.570***	−8.229***	−7.487***	−6.535***	−8.459***	−7.926***
	(-7.23)	(-10.32)	(-5.83)	(-6.69)	(-9.67)	(-5.48)
N	3992	3992	3992	3849	3849	3849

t statistics in parentheses.
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

according to the PHH). Divergently in western China, where PIT Indexes and environmental regulations are weaker, greater investment in anti-pollution initiatives correlates positively with firms upgrading to access Brazilian markets – verifying the PH – and the aftermath of environmental pollution incidents correlates positively with firm exit – simultaneously verifying the PHH. This region-specific confirmation of our second hypothesis definitively illustrates the co-existence of the PH and PHH, but also raises questions that will be addressed in the next section through qualitative methods about firm-level characteristics that might explain this variation in entry/exit alongside the transformations in local environmental regulations across various regions.

To test the final hypothesis, which emphasizes the significance of firm-level global-local interactions as an explanatory factor for the variation and co-existence of the PH and PHH, we once again employ a Probit model (with the same control variables as above) to examine whether firms with more international linkages, defined by the number of products exported and the number of countries to which it exports, are more likely to upgrade to enter the Brazilian market as it transforms with the IA policy, while firms with fewer international linkages are more likely to exit this market as the Brazilian demand shifts. We employ the equations below, for company *i,* city *c* at time *t*:

$$entry_{i,t} / exit_{i,t} = \beta_0 + \beta_1 lnlink_{i,t} + \beta_2 lncgdp_{ct} + \beta_3 lnfdi_{ct} + \beta_4 lnwage_{ct} + \beta_5 lnfoe_{ct} + \beta_6 lnprovpgdp_{ct} + \varepsilon_{c,t}$$

$$entry_{i,t} / exit_{i,t} = \beta_0 + \beta_1 lnproduct_{i,t} + \beta_2 lncgdp_{ct} + \beta_3 lnfdi_{ct} + \beta_4 lnwage_{ct} + \beta_5 lnfoe_{ct} + \beta_6 lnprovpgdp_{ct} + \varepsilon_{c,t}$$

$$entry_{i,t} / exit_{i,t} = \beta_0 + \beta_1 lnlink_{i,t} + \beta_1 lnproduct_{i,t} + \beta_3 lncgdp_{ct} + \beta_4 lnfdi_{ct} + \beta_5 lnwage_{ct} + \beta_6 lnfoe_{ct} + \beta_7 lnprovpgdp_{ct} + \varepsilon_{c,t}$$

The models confirm our third hypothesis. Both measurements of international linkage show positive correlation with entry and negative with exit during the whole period of analysis (Table 4). This fact that the variable international linkages of particular firms affects whether they upgrade/innovate or exit/relocate demonstrates the effect of global-local interactions, and verifies as well how the co-existence of both PH and PHH depends on firm-level characteristics. When put into a single regression (Models 5 and 6), the effect of country-linkages is more significant than the effect of product diversity, which also suggests that it is the exogenous connections of the firm, rather than the endogenous size of the company and scale of production (which might have a proxy in the number of products exported), that drives these global-local interactions that shape PH or PHH behavior.

To deepen our analysis, we distinguish the periods prior to Brazil's IA policy (2000–2005), during its early implementation (2006–2010), and the maturation of its policy effects (2011–2016), and compare the effects of country-linkages between the top 10% most internationally-connected companies and their less-connected competitors. Sample sizes are displayed in Table 5. We find that, for the most connected companies, more international linkages correlated with early entrance into the Brazilian market, and significantly prevented firm exit when the Brazilian market transformed (Table 6a). Moreover, among companies that were not already well-connected internationally, the number of linkages shows a significant and negative relationship with firm exit, but the effect is less strong than the positive effect on firm entry (Table 6b). We interpret these results as a confirmation that strong international linkages at the firm-level explains PH behavior, while weak international linkages at the firm-level explains simultaneous PHH behavior.

In the next section we turn to qualitative case studies that illustrate firm-level heterogeneity in terms of strong/weak international linkages, and firms located in new/traditional agrochemical production clusters. Thereby we can discuss how such variations explain the global-local interactions between Brazil's IA policy, domestic environmental regulations, and the co-existence of PH and PHH in the restructuring of China's agrochemical sector.

7. Qualitative case studies

7.1. Internationally-connected firms from traditional agrochemical production clusters

Rainbow Chemicals[9] was founded in 2001 in the city of Weifang, Shandong province. It is located in the Binhai Economic & Technological Development Area (est. 1995), which became a National Demonstration Eco-Industry Park during the 2000s. This location provides good conditions for upgrading rather than relocation strategies (i.e. PH rather than PHH behavior) (cf. Zeng & Bathelt, 2011). Since its inception, Rainbow's strategy was to attend export markets with customized production. According to its chairman, "we should forget factory-floor [competition], and customize according to the demands of our commercial partners."[10] This attitude emphasizes global-local interactions as factors that might drive PH behavior. Indeed, Rainbow identified the expansion of glyphosate-resistant (transgenic) soy and maize in the US, Argentina, and Brazil since the late 1990s as its primary market, and quickly began to supply atrazine, 2,4-D and other specialized herbicides to transnational companies like Monsanto and Syngenta when this first generation of transgenic crops began to experience weed resistance during the 2000s. Located in an upgraded industrial park that complies with environmental regulations, and responding quickly to international demand for various products, Rainbow's sales increased dramatically and it became China's second largest agrochemical exporter by 2017 (AgNews, 2018).

Rainbow is the first Chinese firm to independently register products for import into Brazil after the IA policy.[11] It did so through a Brazilian contractor that was indicated by a European client,[12] which illustrates that international linkages at the level of export destinations by country (rather than product portfolio and company size) is the key factor that might provide positive effects for PH behavior through global-local interactions. The same contractor would also work for another four Chinese agrochemical firms, all of which were introduced by non-Chinese business partners, as Chinese firms regard each other as competitors and refuse to share such contacts,[13] underscoring the value of international linkages for accessing new markets. Although Rainbow already exported to Brazil indirectly through transnational distributors since its origins, its Brazilian market share increased substantially as its products became approved for direct import. The first approval was obtained in 2011, followed by two products in 2013, five in 2014, eight in 2015, sixteen in 2016, and fourteen in 2018 – with these 46 products approved, Rainbow only trails ChemChina among Chinese firms in Brazil, as the latter incorporated the transnational giants Adama in 2011 and Syngenta in 2016, with their own extensive agrochemical portfolios.[14]

Alongside Rainbow and twenty other companies, the Zhejiang Tide Group was a founding member of the China Crop Protection Industry Association (CCPIA) International Trade Commission in 2012, a committee of the most internationally-oriented agrochemical companies in China who work to "enhance mutual understanding with the global pesticide industry", and counter international trade barriers (CCPIA, 2012). Tide was established in 1994 as an international trade company that exported chemicals from various suppliers across Zhejiang, and consolidated itself as a conglomerate of agrochemical firms from Hangzhou and Ningbo in 2003. Maintaining itself focused on trade, Tide sustained exports even as some suppliers were shut down by stricter environmental regulations in chemical industry parks in the Yangtze delta (cf. Bathelt & Zeng, 2012). This illustrates how stronger international linkages might enable a firm to effectively upgrade with PH behavior, while its own suppliers succumb to pressures for exit or

9 Shandong Weifang Runfeng (Rainbow) Chemical Co., Ltd.

10 Wang Wencai, public remarks at the 8th Crop Protection International Forum, October 7, 2013, Shanghai, China.

11 First author's triangulation of data from MAPA and ANVISA databases.

12 Personal interview by first author with Rainbow's legal representative in Brazil, Porto Alegre, June 22, 2015.

13 Personal interview by first author with Rainbow's contractor in Brazil, Porto Alegre, June 22, 2015.

14 First author's triangulation of data from MAPA and ANVISA databases.

Table 4
International linkage effects on firm entry/exit to Brazilian export markets.

	(1)entry	(2)exit	(3)entry	(4)exit	(5)entry	(6)exit
lnlink	0.0860*** (8.94)	−0.0831*** (-7.84)			0.0928*** (8.83)	−0.0818*** (-6.94)
lnproduct			0.0220** (2.26)	−0.0401*** (-3.59)	−0.0170 (-1.59)	−0.00309 (-0.25)
lncgdp	0.0117 (0.94)	−0.0188 (-1.34)	−0.000202 (-0.02)	−0.00350 (-0.25)	0.0161 (1.26)	−0.0180 (-1.25)
lnfdi	−0.00734 (-0.23)	−0.00225 (-0.06)	0.000245 (0.01)	−0.00719 (-0.20)	−0.00610 (-0.19)	−0.00206 (-0.06)
lnwage	0.0424 (0.75)	0.287*** (4.48)	0.0367 (0.65)	0.288*** (4.49)	0.0399 (0.71)	0.286*** (4.47)
lnfoe	−0.00891 (-0.25)	0.00894 (0.22)	−0.0180 (-0.52)	0.0180 (0.45)	−0.00785 (-0.22)	0.00915 (0.23)
lnprovpgdp	−0.0767 (-1.33)	−0.0826 (-1.25)	−0.0533 (-0.93)	−0.105 (-1.59)	−0.0790 (-1.37)	−0.0830 (-1.26)
_cons	−0.699** (-2.17)	−3.147*** (-8.48)	−0.626* (-1.95)	−3.189*** (-8.60)	−0.688** (-2.14)	−3.145*** (-8.47)
lnsig2u						
_cons	−15.02** (-2.03)	−14.83* (-1.71)	−15.35** (-2.06)	−15.07* (-1.75)	−15.27* (-1.91)	−14.83* (-1.71)
N	23334	23334	23334	23334	23334	23334

t statistics in parentheses.
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 5
Sample size of firms according to their international linkages.

Number of firms		2000–2005	2006–2010	2011–2016
By countries exported	Top 10%	917	1739	1390
	Bottom 90%	3510	7821	7957
By products exported	Top 10%	90	187	159
	Bottom 90%	4337	9373	9188
Total		4427	9560	9347

relocation with PHH behavior.

Tide established a Brazilian subsidiary in 2010, and solicited eleven product registrations for direct import by 2012. The president of the Brazilian subsidiary explained that, following Brazil's IA policy, "the initial plan was to commercialize our agrochemicals by bringing them directly from China," but since "these regulations continued very complex and sluggish," Tide acquired a Brazilian agrochemical company in early 2014 "to put roots in the country [with] a portfolio of products that are already registered, thus speeding up its access to the Brazilian market" (Caetano, 2014). The group's chairman credits their "operating experience" in "high-end markets like the US and Europe" for their ability to access new markets (Agropages, 2012), and considers the acquisition of a Brazilian company "with plenty of pesticide registrations" to be "vital" for the company's "global strategic layout" (Tide, 2015). This reinforces our claim that global-local interactions at the firm-level, particularly the existence of strong international linkages, facilitates PH behavior even while many suppliers succumb to pressures of PHH behavior.

7.2. New entrants to the Brazilian market in new clusters

The Fuhua Tongda Agrochemical Technology Company is located in Leshan, Sichuan province. It was originally a paper-making company that expanded vertically to produce the main chemical products needed for paper manufacturing. When facing overproduction of sodium hydroxide (lye), it identified an opportunity to synthesize it into glyphosate, and was restructured into an agrochemical firm in 2007. At that moment, demand for the active ingredient of glyphosate-based herbicides mushroomed with Brazil's soy boom and IA policy, but many producers in China's traditional agrochemical clusters could not scale-up due to environmental restrictions. Located in an agrochemical industrial park of its own, but facing looser environmental regulations in western China, Fuhua became China's largest glyphosate producer and third largest agrochemical exporters by the early 2010s (IPE/NRDC, 2010; CCPIA, 2014). In this first moment and in comparison with other firms facing stricter environmental regulations in eastern China, Fuhua's case appears to verify the PHH in the regional shift of agrochemical production. Firm-level considerations of global-local interactions, however, complicates this analysis. Fuhua has far fewer products for export than Rainbow or Tide, but it established strong international linkages through the CCPIA International Trade Commission, hired a Brazilian agrochemical registration company in 2009 (DCI, 2009), and established direct exports of glyphosate to Brazil by 2012.[15] With this boost in revenues, Fuhua was able to invest 2 million RMB to upgrade its wastewater treatment facilities, and thus maintain exports to Brazil even as other competitors in western China exited the market (Fig. 2). In this later moment and in comparison with other firms in western China facing a later onset of environmental regulations, Fuhua's case also exemplifies how strong international linkages enable firms to assume PH behavior instead.

Nutrichem is another illustrative new entrant. It was founded in 2003 by agrochemical engineers in Beijing, a hub of chemical research and development (R&D) rather than industrial production. Seeing that most Chinese firms were competing on high-volume/low-cost herbicides (like glyphosate and 2,4-D), Nutrichem's founders decided to distinguish themselves instead through the production of higher value but still

[15] First author's triangulation of data from MAPA and ANVISA databases.

generic (off-patent) pesticides. "We are a high tech firm," a senior executive explained, "that makes us different from the other companies. Our market strategy is to find and create products for niche markets … Maybe our volume is not so big, but we can make a lot of money."[16] The strategy worked, and illustrates that global-local interactions in the form of identifying and accessing niche export markets can also induce PH behavior. Nutrichem not only avoided competition with firms like Rainbow and Fuhua, but surpassed them in exports-by-value with new products to control glyphosate-resistant weeds, such as metolachlor, and specialized fungicides like tebuconazole.[17] Nutrichem incorporated subsidiaries in well-established agrochemical industrial parks in Hebei, Jiangsu, and Zhejiang, which had already cleared the strictest environmental regulations,[18] and tapped its extensive international-linkages to undertake a three-prong strategy to access Brazilian markets: in 2011, it invested in a Brazilian partner that obtained approval to import Nutrichem products directly as early as 2009, and hired specialists from German and Australian firms to establish a Brazilian subsidiary of its own, which began to secure approvals for direct imports in 2014, the same year Nutrichem also invested in a US firm with an agrochemical factory in Brazil, which gained approval to import additional Nutrichem products in 2017.[19] Both Fuhua and Nutrichem exemplify new entrants that leveraged international linkages to seize opportunities for market-expansion in the aftermath of Brazil's IA policy. Interestingly, their capacity to upgrade production and product portfolio illustrates PH behavior due to global-local interactions, even as Fuhua gained PHH relocation rents in its early stages, and both firms de-concentrated China's agrochemical industry from eastern provinces.

7.3. Firms with few international linkages that exited the market due to environmental restrictions

During the 2012 national agrochemical symposium of the CCPIA in Shanghai, the Regulatory Affairs Director of Milenia, a Brazilian subsidiary of the Adama agrochemical company acquired by ChemChina the previous year, characterized the confluence of Brazil's IA policy with increasingly more stringent environmental regulations in China as follows: "We view this trend as very positive for those companies that intend to be in the market for the long term. They'll necessarily have to invest in top standards of quality to be allowed to sell in the Brazilian market. Opportunistic approaches will disappear" (CCPIA, 2012, p. 21). In other words, he was confident that PH behavior would begin to outpace PHH behavior among Chinese agrochemical firms. Indeed, the number of Chinese agrochemical companies exporting to Brazil more than doubled between 2005 and 2010 (Table 6), but that expansion then halted and many smaller companies outside agrochemical industrial clusters exited the Brazilian market entirely by 2016. A region where these "opportunistic" dynamics of de-concentration/re-concentration seem evident is western Shaanxi province, particularly the cities of Xi'an, Baoji, Xianyang, and Hanzhong (Fig. 5), which illustrates how our second and third hypotheses are confirmed in western China. In other words, these cases illustrate the co-existence of PH and PHH driven by global-local interactions in the form of firm-level international linkages.

Shaanxi ranks among the worst provinces in terms of environmental incidents and PIT Index (IPE/NRDC, 2010; Cao et al., 2018), and many agrochemical industries were not located in specialized industrial parks. High-profile accidents in smelting plants in Baoji caused public alarm in 2008, and the provincial government initiated a crackdown on hazardous industries across the region (Xinhua, 2009). Companies like Hanzhong Chemical Pesticides and Qinfeng Agrochemicals in Xinyang likely account for the increase of exports to Brazil from those cities between 2000 and 2008. In other words, they illustrate PHH behavior in effect. By 2009, however, both companies faced financial difficulties associated with the imposition of stricter environmental regulations and the general slowdown of international demand, and by 2011 both were acquired by larger competitors in Xi'an, which transferred production to their own industrial park (Birkett, 2011; Agropages 2011). That is, the Xi'an-based firms with stronger international linkages and capacity for PH behavior ultimately re-concentrated agrochemical production in the region. Similarly, Baoji Guokang Bio-technologies appears to have exported small volumes to Brazil since 2010, but exited the market in 2015, apparently without sufficient international partners willing to invest in the registration of their products for direct import to Brazil. This suggests that, despite the rents to be gained from exploiting PHH behavior at the local level, global-local interactions in the form of weak international linkages might still curtail a firm's capacity to translate such gains into new investments that sustain its market share and allow for subsequent PH upgrading.

8. Discussion of qualitative case studies in relation to theory and quantitative analysis

The case studies examined above illustrate firm-level heterogeneity in terms of global-local interactions, understood through the lens of international linkages by number of countries and products for export. In relation to the quantitative verification of H1, the first two sets of firms with strong international linkages (Rainbow and Tide in traditional clusters, and Fuhua and Nutrichem in new clusters) provide qualitative corroboration of the fact that Brazil's IA policy had an effect in the spatial restructuring and upgrading of China's agrochemical sector, as all four companies did begin seeking product registrations in Brazil after 2006 and thereby increased their exports in subsequent years. Meanwhile, the companies in Shaanxi that lacked strong international linkages never show up in Brazilian government databases or interviews about Chinese firms registering products in Brazil in the aftermath of the IA policy.

Second, the quantitative and qualitative analyses of H2 also dovetail in the fact that the whole set of firms in the case studies above illustrate national-level co-existence of PH and PHH. The case studies also echo the fact that such behaviors are not clearly distinguishable in traditional clusters in eastern China, where Tide upgraded even while many of its local suppliers exited or relocated. Meanwhile, PH and PHH behavior are much more clearly distinguishable in western China, where Fuhua and firms in the Shaanxi cluster emerged through opportunist PHH behavior in high-volume/low-cost agrochemicals, but in later stages they were forced to shut down or upgrade due to increasing costs of environmental compliance (i.e. PH behavior). Moreover, the main distinction between Fuhua (alongside Rainbow, Tide, and Nutrichem) and most firms in the Shaanxi cluster is their level of international linkages, dovetailing with the quantitative verification of H3 and illustrating how global-local interactions are also relevant factors determining PH or PHH behavior at the firm-level.

9. Conclusion

The agrochemical IA policy in Brazil was effective, and Chinese firms were some of its primary beneficiaries. As demand increased in Brazil and this new policy raised prospects for direct exports by Chinese manufacturers, China's agrochemical industry embarked in a period of regional expansion and experimentation between 2000 and 2010, with new entrants from regions beyond China's traditional agrochemical

[16] Personal interview by first author, Beijing, April 22, 2015.

[17] Data triangulated by first author between interview with Nutrichem executive, CCPIA's data on the leading agrochemical export companies, and the CCPIA product directory (March 2013 edition).

[18] Interview by first author with Nutrichem executive, referring to production facilities in Jiangjiakou, Yangcheng, and Shaoxing.

[19] First author's triangulation of data on agrochemical product registrations by CCAB Agro and Albaugh/Atanor, the Brazilian and US companies into which Nutrichem made minority investments, and Nutrichem's Brazilian subsidiary Proventis Lifesciences, on MAPA/ANVISA database.

Table 6

a. Effect of international linkages (by country) on top 10% most connected firms

	2000–2005		2006–2010		2011–2016	
	(1)entry	(2)exit	(3)entry	(4)exit	(5)entry	(6)exit
lnlink	0.194***	0.138	−0.103	−0.379***	−0.167**	−0.521***
	(3.24)	(1.49)	(-1.49)	(-5.01)	(-1.98)	(-6.67)
lncgdp	0.0400	−0.0339	−0.0228	−0.0498	0.115*	0.0783
	(0.63)	(-0.36)	(-0.43)	(-0.74)	(1.68)	(1.21)
lnfdi	−0.338	−0.313	0.209*	0.141	−0.111	0.0624
	(-1.54)	(-0.94)	(1.71)	(0.89)	(-0.59)	(0.35)
lnwage	−0.0997	0.502	−0.486*	0.464	0.806*	0.462
	(-0.21)	(0.67)	(-1.66)	(1.24)	(1.83)	(1.09)
lnfoe	0.328	0.384	−0.102	0.0447	−0.0141	−0.0425
	(1.38)	(1.03)	(-0.71)	(0.24)	(-0.07)	(-0.24)
lnprovpgdp	−0.126	−0.0940	−0.0546	−0.279	−0.0166	−0.333
	(-0.42)	(-0.21)	(-0.22)	(-0.84)	(-0.05)	(-0.90)
_cons	−0.380	−7.402	4.293**	−3.361	−9.138**	−1.492
	(-0.12)	(-1.51)	(2.47)	(-1.53)	(-2.47)	(-0.42)
lnsig2u						
_cons	−14.50	−12.53	−14.89	−10.55	−12.97	−15.59
	(-0.67)	(-0.46)	(-0.77)	(-0.67)	(-0.60)	(-0.65)
N	917	917	1739	1739	1390	1390

6b. Effect of international linkages (by country) on bottom 90% most connected firms

	2000–2005		2006–2010		2011–2016	
	(1)entry	(2)exit	(3)entry	(4)exit	(5)entry	(6)exit
lnlink	0.217***	0.0321	0.176***	−0.0281	0.170***	−0.0791***
	(8.04)	(1.04)	(9.58)	(-1.39)	(9.61)	(-4.34)
lncgdp	−0.00593	−0.00271	−0.0445**	−0.0442*	0.0158	−0.00945
	(-0.18)	(-0.07)	(-2.08)	(-1.80)	(0.70)	(-0.39)
lnfdi	0.237**	0.307**	−0.0217	−0.0549	−0.0670	−0.0623
	(1.98)	(2.16)	(-0.43)	(-0.93)	(-1.11)	(-0.96)
lnwage	0.0397	0.211	−0.0869	0.227*	0.187	0.0240
	(0.17)	(0.75)	(-0.79)	(1.80)	(1.44)	(0.17)
lnfoe	−0.304**	−0.325**	0.0103	0.0939	0.0443	0.0529
	(-2.34)	(-2.11)	(0.18)	(1.40)	(0.73)	(0.81)
lnprovpgdp	0.0265	−0.0288	0.0321	−0.0995	−0.115	−0.0332
	(0.18)	(-0.17)	(0.32)	(-0.87)	(-0.95)	(-0.26)
_cons	−0.619	−2.033	−0.391	−2.770***	−2.055*	−0.867
	(-0.40)	(-1.12)	(-0.58)	(-3.55)	(-1.88)	(-0.73)
lnsig2u						
_cons	−23.41	−15.39	−14.95	−13.83	−23.17	−14.61
	(-0.14)	(-0.45)	(-1.22)	(-1.45)	(-0.01)	(-1.25)
N	3510	3510	7821	7821	7957	7957

t statistics in parentheses.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

production clusters. Many of these firms tapped the Brazilian market through opportunist PHH behavior, which explains the expansion and de-concentration of the sector during this period. However, stricter environmental regulations and greater enforcement in the aftermath of environmental pollution incidents gradually halted this expansion, particularly in western China. The Brazilian market became dominated by major exporters from China's traditional agrochemical clusters, alongside the most internationally-linked new entrants from other regions who were able to overcome environmental challenges through upgrading production and/or restructuring supply. Thus, these global-local interactions resulted in a period of consolidation in China's agrochemical sector from 2010 to 2016, that is ultimately shaped more by PH behavior. Nonetheless, both quantitative and qualitative analyses of the entire period and of regional-level dynamics illustrates clearly the simultaneous co-existence of PH and PHH, and the significance of global-local interactions, identified in terms of international linkages at the firm-level, as a statistically significant and qualitatively evident factor determining the variations and co-existence of PH and PHH behavior.

These empirical findings regarding China-Brazil agrochemical trade and regional industrial restructuring support our theoretical approach, which synthesizes frameworks of global political ecology and EEG into an evolutionary *political economy* approach to applied geography, or evolutionary political economic geography (EPEG). While the usual EEG

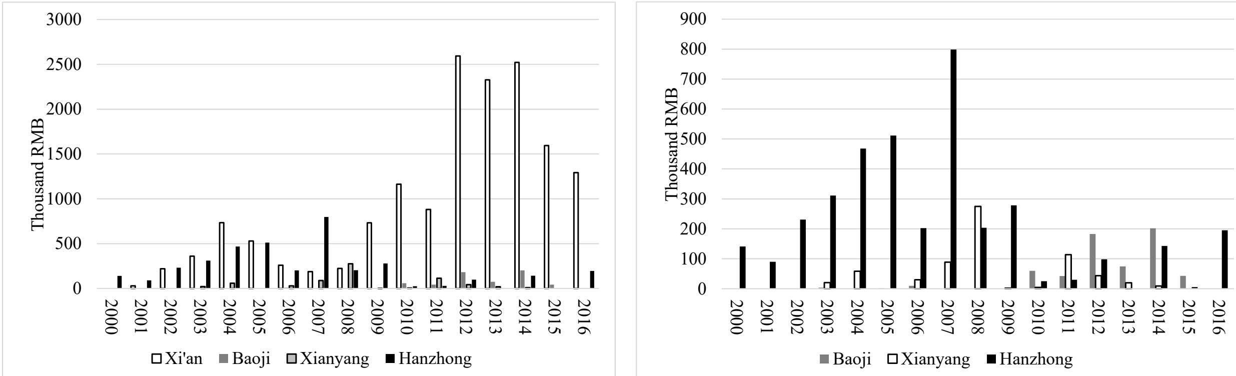

Fig. 5. Agrochemical exports to Brazil from selected Shaanxi cities (RMB), 2000–2016.
Source: Elaborated by the authors from China customs data.

quantitative analysis identified statistically significant correlations between exogenous characteristics of firms and regional industrial restructuring, qualitative case studies with a political ecology approach enabled verification that these global-local interactions can indeed explain when, where, and why particular firms adopt PH or PHH behavior. Moreover, these empirical findings not only support the fruitfulness of our theoretical synthesis, they also add further dimensions to critiques we have made elsewhere of simplistic accounts of environmental Kuznets curves, as "export upgrading can, but does not necessarily, lead to environmental improvement" (Mao & He, 2017, p. 105), and attention to firm-level behavior similarly challenges linear accounts of environmental modernization (Zhu et al., 2014; Zhou, Zhu, & He, 2017; Oliveira, 2018, 2019).

Our study has two important limitations. First, narrowing the empirical scope to Chinese agrochemical exports to Brazil enables a clear examination of global-local interactions, but it reduces the empirical basis for examination of international linkages as a relevant characteristic of firm heterogeneity driving the co-existence of PH and PHH in pollution-intensive industries more generally. Still, our study provides a strong foundation for further research on global-local interactions in industrial sectors where environmental regulations and international trade policies may drive conflicting trends of spatial deconcentration and re-concentration. Second, although the effect of Brazil's IA policy on China's total agrochemical exports to Brazil was verified through both quantitative and qualitative analysis, the examination of global-local interactions is refracted through the number of international linkages at the firm-level, which some critics might claim reduces our ability to make more robust statements about direct effect of Brazil's IA policy on China's agrochemical industry. Nonetheless, we believe that, in examining firm heterogeneity in terms of international linkages as a determinant factor of PH or PHH, we are not simply assembling models and cases of independent effects from shifts in international trade and domestic environmental regulations, but a combined effect of firm-level upgrading and exit/relocation due to global-local interactions. Ultimately, as a pioneering study on this topic, such limitations may reasonably motivate a call for further investigations of our theory.

The policy relevance and implications of our study are palpable. Brazilian agrochemical regulation policies were revised once again in 2016, and more products have been registered and approved for production/import in the past two years than during the prior five years combined.[20] A new law is expected to be promulgated soon, consolidating fast-track agrochemical registration in Brazil. Meanwhile, the Chinese government has adopted policies to achieve zero-growth in domestic agrochemical consumption by 2020 (Jin & Zhou, 2018), and stricter enforcement of environmental regulations continue to drive agrochemical firms to upgrade, relocate, or shut down (Wang, 2019). Consequently, the future growth of China's agrochemical sector will be even more influenced by imports from Brazil, and the global-local interactions examined here will become even more important factors in the restructuring of the sector through PH and PHH behavior. The application of both quantitative and qualitative geographical analysis, particularly at fine-grained firm-level, will continue to be essential for the assessment and management of the agrochemical industry, particularly its environmental regulations, repercussions, and associated global economic transformations. Our findings indicate that local governments should be skeptical about the effectiveness of PHH-inducing policies, as the investment and economic-growth gains from industrial relocation prove to be very short-term and ephemeral, while the most successful companies and local industrial clusters are those that embrace fully the PH imperative to upgrade environmental standards to offset compliance costs and identify commercial innovations that generate new competitive advantages in a rapidly shifting international landscape.

Declaration of competing interest

No potential conflict of interest was reported by the authors.

CRediT authorship contribution statement

Gustavo de L.T. Oliveira: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing - original draft, Writing - review & editing. **Canfei He:** Conceptualization, Data curation, Funding acquisition, Project administration, Resources, Software, Supervision. **Jiahui Ma:** Formal analysis, Methodology, Validation, Visualization, Writing - original draft, Writing - review & editing.

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[20] 854 agrochemicals were approved in 2017–2018, while 842 were approved in 2012–2016, according to MAPA and ANVISA databases.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apgeog.2020.102244.

Appendix 1

Firm level entry/exit/maintenance of Brazilian export market, central China (2000–2016).

	(1)	(2)	(3)	(4)	(5)	(6)
	entry	exit	maintain	entry	exit	maintain
lninv	0.00160	0.0107	0.103*			
	(0.05)	(0.25)	(1.71)			
lnacc				0.00875	−0.0401	−0.0133
				(0.28)	(-1.25)	(-0.44)
lncgdp	0.00182	0.0258	−0.116**	−0.00478	0.0349	−0.119**
	(0.08)	(1.03)	(-2.40)	(-0.21)	(1.57)	(-2.53)
lnfdi	−0.101	−0.0536	0.0485	−0.194	0.0141	0.143
	(-0.89)	(-0.54)	(0.32)	(-1.51)	(0.11)	(1.13)
lnwage	0.520***	0.630***	−0.151	0.486**	0.628***	−0.319
	(2.66)	(2.85)	(-0.49)	(2.55)	(3.03)	(-1.03)
lnfoe	0.0866	0.142	0.0175	0.0835	0.151	−0.00775
	(0.93)	(1.57)	(0.18)	(0.95)	(1.62)	(-0.08)
lnprovpgdp	−0.109	−0.218	0.659**	0.0304	−0.327	0.798**
	(-0.65)	(-0.97)	(2.01)	(0.17)	(-1.54)	(2.44)
_cons	−5.767***	−6.895***	−7.294***	−6.200***	−6.074***	−6.040***
	(-6.16)	(-7.93)	(-7.30)	(-6.71)	(-6.13)	(-7.23)
N	7007	7007	7007	6873	6873	6873

t statistics in parentheses.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Appendix 2

Firm level entry/exit/maintenance of Brazilian export market, eastern China (2000–2016).

	(1)	(2)	(3)	(4)	(5)	(6)
	entry	exit	maintain	entry	exit	maintain
lninv	0.0658***	0.0866***	0.180***			
	(3.70)	(4.12)	(6.56)			
lnacc				−0.0207	−0.0305**	−0.0343*
				(-1.09)	(-2.02)	(-1.75)
lncgdp	−0.0376**	−0.0352*	−0.117***	−0.0575**	−0.0640*	−0.178***
	(-2.47)	(-1.89)	(-2.71)	(-1.96)	(-1.93)	(-2.75)
lnfdi	−0.0285	−0.0698*	−0.0321	0.0116	−0.0150	0.0703
	(-0.88)	(-1.94)	(-0.45)	(0.38)	(-0.37)	(0.76)
lnwage	0.00837	0.241*	−0.298	0.0343	0.270	−0.168
	(0.05)	(1.66)	(-1.42)	(0.15)	(1.35)	(-0.70)
lnfoe	0.0126	0.0478	−0.0330	−0.00547	0.0175	−0.0794
	(0.27)	(1.22)	(-0.36)	(-0.14)	(0.44)	(-0.73)
lnprovpgdp	0.296**	0.210*	0.884***	0.285	0.208	0.815***
	(2.03)	(1.74)	(3.91)	(1.55)	(1.32)	(3.30)
_cons	−5.187***	−7.126***	−8.434***	−4.457***	−6.161***	−6.641***
	(-7.19)	(-11.81)	(-10.11)	(-6.77)	(-11.32)	(-7.60)
N	44182	44182	44182	42477	42477	42477

t statistics in parentheses.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

References

AgNews. (2018). "Rainbow ranked as number 1 agrochemical exporter in 2017." AgNews, March 15. http://news.agropages.com/News/NewsDetail—25704.htm Accessed November 1, 2019.
Agropages. (2011). *China Agri-Business Acquired Shaanxi Qinfeng Agrochemical*. June 28 http://news.agropages.com/News/print-4368.htm (accessed June 24, 2019).
Agropages. (2012). "Tide Group, integrating high quality into global sales system" December 4 (accessed June 10, 2019) http://news.agropages.com/News/print-8510.htm.
Bathelt, H., & Zeng, G. (2012). Strong growth in weakly-developed networks: Producer–user interaction and knowledge brokers in the Greater Shanghai chemical industry. *Applied Geography, 32*(1), 158–170.
Binimelis, R., Pengue, W., & Monterroso, I. (2009). Transgenic treadmill: Responses to the emergence and spread of glyphosate-resistant Johnsongrass in Argentina. *Geoforum, 40*(4), 623–633.
Birkett, R. (2011). "Two Shaanxi China-based agchem firms merge." December 8, IEG policy agribusiness intelligence (accessed June 20, 2019) https://iegpolicy.agribusinessintelligence.informa.com/AG005542/Two-Shaanxi-Chinabased-agchem-firms-merge.
Bombardi, L. (2013). "Violencia Silenciosa: O uso de Agrotoxicos no Brasil" (Silent Violence: Agrotoxic use in Brazil). In *Annals of the 6th International Symposium of Agrarian Geography*. João Pessoa: Federal University of Paraíba.
Bombardi, L. (2017). *Geografia do uso de agrotóxicos no Brasil e conexões com a União Europeia (Geography of the use of agrotoxins in Brazil and connections with the European Union)*. São Paulo: University of São Paulo Press.
Caetano, M. (2014). "Chinesa Tide acerta aquisição e acelera seu avanço no país" (Chinese Tide sets acquisition and accelerates its advance in the country). *Valor Econômico*. April 4. Available at: http://www2.valor.com.br/agro/3505594/chinesa-tide-acerta-aquisicao-e-acelera-seu-avanco-no-pais, 2011.
Cao, G., Yang, L., Liu, L., Ma, Z., Wang, J., & Bi, J. (2018). Environmental incidents in China: Lessons from 2006 to 2015. *The Science of the Total Environment, 633*, 1165–1172.
China Crop Protection Industry Association (CCPIA). (2012). *China agrochemicals*. Shanghai: CCPIA. December.
China Crop Protection Industry Association (CCPIA). (2014). *China agrochemicals*. Shanghai: CCPIA. June.
Coe, N. (2012). Geographies of production II: A global production network a–z. *Progress in Human Geography, 36*(3), 389–402.
Comtrade. (2019). *UN international trade statistics database*. https://comtrade.un.org/. (Accessed 20 April 2019).
Copeland, B., & Taylor, M. (2004). Trade, growth, and the environment. *Journal of Economic Literature, 42*(1), 7–71.
Dam, L., & Scholtens, B. (2008). Environmental regulation and MNEs location: Does CSR matter? *Ecological Economics, 67*(1), 55–65.
DCI. (2009). "Chineses vêm ao Brasil para disputar setor de defensivos" (Chinese come to Brazil to compete in agrohemical sector). August 4. Available at: https://www.investe.sp.gov.br/noticia/chineses-vem-ao-brasil-para-disputar-setor-de-defensivos/ Accessed June 10, 2019.
Dean, J., Lovely, M., & Wang, H. (2009). Are foreign investors attracted to weak environmental regulations? Evaluating the evidence from China. *Journal of Development Economics, 90*(1), 1–13.
Duan, W., Chen, G., Ye, Q., & Chen, Q. (2011). The situation of hazardous chemical accidents in China between 2000 and 2006. *Journal of Hazardous Materials, 186*(2–3), 1489–1494.
Institute of Public and Environmental Affairs (IPE) and Natural Resources Defense Council (NRDC). (2010). *Environmental open information: Between advance and retreat*. Beijing: NRDC.
Feng, S. (2008). 2007年石油和化工行业回顾及2008年展望 (2007 review and prospects for China's oil and chemical industry in 2008). *Chemical Industry, 26*(3), 1–8.
Fonseca, J. (2018). *"A regulação de registro de novas moléculas do setor de defensivos agrícola" (Regulation of registration of new molecules in the agrochemical sector)*. MA thesis. Department of Agribusiness. Getúlio Vargas Foundation.
He, C., & Zhu, S. (2019). *Evolutionary economic geography in China*. Singapore: Springer.
Horner, R. (2016). A new economic geography of trade and development? Governing south–south trade, value chains and production networks. *Territory, Politics, Governance, 4*(4), 400–420.
Horner, R., & Nadvi, K. (2018). Global value chains and the rise of the Global South: Unpacking twenty-first century polycentric trade. *Global Networks, 18*(2), 207–237.
Jeppesen, T., & Folmer, H. (2014). The confusing relationship between environmental policy and location behaviour of firms: A methodological review of selected case studies. *The Annals of Regional Science, 35*(4), 523–546.
Jin, S., & Zhou, F. (2018). Zero growth of chemical fertilizer and pesticide use: China's objectives, progress and challenges. *Journal of Resources and Ecology, 9*(1), 50–59.
KPMG. (2013). *China's chemical industry: The emergence of local champions*. Amstelveen, Netherlands: KPMG.
Koenig, P., Mayneris, F., & Poncet, S. (2010). Local export spillovers in France. *European Economic Review, 54*(4), 622–641.
Kumar, S., & Managi, S. (2009). "Win–win opportunities and environmental regulation: Test of the porter hypothesis". In S. Managi, & S. Kumar (Eds.), *The economics of sustainable development: The case of India* (pp. 157–166). New York: Springer.
Li, & Fung Research Centre. (2008). *China's industry relocation and upgrading trends: Implications for sourcing business, China distribution & trading*. Hong Kong: Li & Fung Research Centre.
Lin, L., Moon, J. J., & Yin, H. (2014). Does international economic integration lead to a cleaner production in China? *Production and Operations Management, 23*(4), 525–536.
Lin, G., Wang, C., Zhou, Y., Sun, Y., & Wei, Y. (2011). Placing technological innovation in globalising China: Production linkage, knowledge exchange and innovative performance of the ICT industry in a developing economy. *Urban Studies, 48*(14), 2999–3018.
Macauhub. (2007). Chinese companies want to export pesticides to Brazil. Macauhub, April 24 https://macauhub.com.mo/2007/04/24/2919/ (accessed May 23, 2017).
Mao, X., & He, C. (2017). Export upgrading and environmental performance: Evidence from China. *Geoforum, 86*, 150–159.
Martin, R. (2010). Roepke lecture in economic geography: Rethinking regional path dependence: Beyond lock-in to evolution. *Economic Geography, 86*(1), 1–27.
Oliveira, G.de L. T. (2018). The Battle of the Beans: How direct Brazil-China soybean trade was stillborn in 2004. *Journal of Latin American Geography, 17*(2), 113–139.
Oliveira, G.de L. T. (2019). Boosters, brokers, bureaucrats, and businessmen: Assembling Chinese capital with Brazilian agribusiness. *Territory, Politics, Governance, 7*(1), 22–41.
Oliveira, G.de L. T., & Hecht, S. (2016). Sacred groves, sacrifice zones, and soy production: Globalization, intensification and neo nature in South America. *Journal of Peasant Studies, 43*(2), 251–285.
Oliveira, G.de L. T., McKay, B., & Plank, C. (2017). How biofuel policies backfire: Misguided goals, inefficient mechanisms, and political-ecological blind spots. *Energy Policy, 108*, 765–775.
Oliveira, G.de L. T., & Schneider, M. (2016). The politics of flexing soybeans: China, Brazil, and global agroindustrial restructuring. *Journal of Peasant Studies, 43*(1), 167–194.
Peet, R., Robbins, P., & Watts, M. (2011). *Global political ecology*. London: Routledge.
Pelaez, V., da Silva, L., Guimarães, T., Dal Ri, F., & Teodorovicz, T. (2015). A (des) coordenação de políticas para a indústria de agrotóxicos no Brasil (The (dis) coordination of policies for agrotoxin industries in Brazil). *Revista Brasileira de Inovação*, (14), 153–178.
Pelaez, V., Terra, F., & Silva, L. (2010). A regulamentação dos agrotóxicos no Brasil: Entre o poder de mercado e a defesa da saúde e do meio ambiente (Regulation of agrochemicals in Brazil: Between market power and the defense of health and the environment). *Revista de Economia, 36*(1), 27–48.
Perlitz, U. (2005). *Chemieindustrie in China: international auf der Uberhospur [Chemical industry in China: Overtaking internationally]. Deutsche Bank Research: Aktuelle Themen* (Vol. 333). Frankfurt/Main: China Spezial.
Porter, M. E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives, 9*(4), 97–118.
Santos, G. (2012). *Características, sistema de registros de produtos e concorrência no mercado de agrotóxicos no Brasil (Characteristics of the system of product registration and competition in Brazil's agrotoxic market)*. Brasília: IPEA.
Shen, J., Wei, Y., & Yang, Z. (2017). The impact of environmental regulations on the location of pollution-intensive industries in China. *Journal of Cleaner Production*, (148), 785–794.
Shi, X., & Xu, Z. (2018). Environmental regulation and firm exports: Evidence from the eleventh Five-Year Plan in China. *Journal of Environmental Economics and Management, 89*, 187–200.
Silva, M., & Costa, L. (2012). A indústria de defensivos agrícolas (The agrochemical industry). *BNDES Setorial, 35*, 233–276.
Tide. (2015). *Tide do Brazil acquired Prentis Quimica*. Press release. February 9 http://www.tide-china.com/en/news_show.aspx?id=110. (Accessed 10 June 2019).
Tole, L., & Koop, G. (2011). Do environmental regulations affect the location decisions of multinational gold mining firms? *Journal of Economic Geography, 11*(1), 151–177.
Valor. (2007). *"China mira mercado de agrotóxicos do Brasil" (China targets Brazilian agrotoxic Market)*. Valor Online. April 23. Available at: http://g1.globo.com/Noticias/Economia_Negocios/0,,MUL25689-9356,00-CHINA+MIRA+MERCADO+DE+AGROTOXICOS+DO+BRASIL.html (accessed May 23, 2017).
Wang, N. (2019). *1,176 chemical enterprises in China to relocate and upgrade*. ChemLinked. April 25. Available at: https://chemlinked.com/news/chemical-news/1176-chemical-enterprises-china-relocate-and-upgrade Accessed April 26, 2019.
Wang, C., Lin, G., & Li, G. (2010). Industrial clustering and technological innovation in China: New evidence from the ICT industry in Shenzhen. *Environment & Planning A, 42*(8), 1987–2010.
Wheeler, D., et al. (1999). *Greening Industry: New Roles for Communities, Markets, and Governments. World Bank policy research report 19851*. New York: Oxford University Press.
Wu, H., Guo, H., Zhang, B., & Bu, M. (2017). Westward movement of new polluting firms in China: Pollution reduction mandates and location choice. *Journal of Comparative Economics, 45*, 119–138.
Xinhua. (2009). *Smelter at center of led poisoning scandal shut down*. Xinhua News Agency. August 18. Available at: http://www.china.org.cn/china/news/2009-08/18/content_18355625.htm Accessed April 26, 2019.
Yang, C. (2012). Restructuring the export-oriented industrialization in the Pearl River Delta, China: Institutional evolution and emerging tension. *Applied Geography, 32*(1), 143–157.

Yasar, M., & Paul, C. (2007). International linkages and productivity at the plant level: Foreign direct investment, exports, imports and licensing. *Journal of International Economics, 71*(2), 373–388.
Yeung, H. (2007). Remaking economic geography: Insights from East Asia. *Economic Geography, 83*(4), 339–348.
Zeng, G., & Bathelt, H. (2011). Divergent growth trajectories in China's chemical industry: The case of the newly developed industrial parks in Shanghai, Nanjing and Ningbo. *Geojournal, 76*(6), 675–698.
Zhou, Y., Zhu, S., & He, C. (2017). How do environmental regulations affect industrial dynamics? Evidence from China's pollution-intensive industries. *Habitat International, 60*, 10–18.
Zhu, S., & He, C. (2019). Moving beyond Anglo-American economic geography: The significance of non-Anglo-American model. *International Journal of Urban Sciences, 23*(2), 191–197.
Zhu, S., He, C., & Liu, Y. (2014). Going green or going away: Environmental regulation, economic geography and firms' strategies in China's pollution-intensive industries. *Geoforum, 55*, 53–65.
Zhu, S., & Pickles, J. (2014). Bring in, go up, go west, go out: Upgrading, regionalisation and delocalisation in China's apparel production networks. *Journal of Contemporary Asia, 44*(1), 36–63.