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Mobilizing the Matrix of Tropical Agro-Innovation: Multi-Locational Agents and Inter-Regional Learning in South American Agro-Industrial Systems

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Multi-Locational Agents and Inter-Regional Learning in South American Agro-Industrial Systems

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Urban Planning

by

George Lee Mackey III

2016

ABSTRACT OF THE DISSERTATION

Mobilizing the Matrix of Tropical Agro-Innovation:

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by

George Lee Mackey III

Doctor of Philosophy in Urban Planning

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Professor Susanna B. Hecht, Chair

In tropical territories, the factors behind technological change in agro-industries encompass an increasingly diverse set of sectors, social agents, and political ecologies. One question that remains under-explained is how and why tropical agro-industrial systems form relationships to distant regions as part of the production of knowledge. This dissertation contributes to the literature on the geographical organization of innovation in tropical agro-regions by explaining the multi-locational dimension of knowledge production within South American agro-industrial systems. Three levels of analysis use novel evidence from multi-sited fieldwork and datasets to examine knowledgeable agents that base their work in locational “hotspots” of agro-innovation within Brazil and engage in spatial mobility to regions within Latin America. I argue that inter-regional matrices of learning form through mobile agents from Brazil that carve out new relations to places and peoples in varied localized contexts of knowledge production within Latin

America. The findings suggest that an inter-regional matrix produces learning from a wider spectrum of knowledge that spills over from locations within Latin America into innovation in home regions within Brazil in the globalizing context of growth in emerging economies and planetary climate change.

The first analytical level explains different relational arrangements of regional systems of social circulation from South America through a comparative history of two tropical territories that varied in their processes of distant learning through the mobility of “local” university-based plant scientists. The second analytical level explains the recent cross-border geography of scientific mobility of the Brazilian Agricultural Research Corporation through an integration of otherwise “peripheral” locations and dimensions of knowledge within Latin America into a framework of knowledge spill-ins. The third analytical level suggests the potential for cross-border learning by large agro-industrial firms from Brazil through more granular branch-level analysis of the location, specialization and organization of Latin American subsidiaries. I argue that this select set of empirical and conceptual tools demonstrate the inter-regional prism of knowledge-based dimensions of agro-industrial organization, environmental conservation and multi-scalar governance in tropical territories during a globalizing era that expresses uncertain geographical shifts in comparison to the “Green Revolution” era of agricultural technology after World War II.

The dissertation of George Lee Mackey III is approved.

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2016

To my parents, who value knowledge and life beyond borders

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Chapter One. Introduction

The Andean peaks that soar over the arid plateau above La Paz, Bolivia were shrouded in darkness on the February morning in 2007 when President Evo Morales took to flight. First light broke as the presidential jet passed over the tropical slope that falls precipitously to the patchwork of forests and farms of the *cerrado*, the wooded savanna that extends across the border to Brasilia, the capital of Brazil. The Planalto Palace in the city center is where the Brazilian President at the time, Luiz Inácio da Silva, and President Morales would negotiate new international accords. Since the turn of the century, analysts increasingly asked why and how relations were shifting between the emerging economy of Brazil and developing economies across Latin America and Africa. The traditional starting points of explanation are Brazil's head of state or the esteemed diplomats next door in the Itamaraty Palace. The present work also explains new channels between Brazil and Latin America over this period but it explores an alternate set of more decentralized relations - of innovation in the tropics - that remain largely unexplored. This dissertation contributes to the literature on the geographical organization of innovation in tropical agro-regions by constructing an explanatory framework of the multi-locational dimension of knowledge production within South American agro-industrial systems.

In the recent era of the globalizing growth of emerging economies and concerns over planetary climate change, what explains territorial processes of innovation in tropical agro-industrial systems? Innovation increasingly refers not only to the traditional focus on the dissemination of seeds to isolated farmers. It also includes interactions between a broader set of sectors, social agents and political ecologies that shape "technologies" in the form of products, processes and institutions. Analysts of emerging economies have begun to map "hotspot" locations in which interactions between knowledgeable agents from science, business, public

institutions and civil society form processes of innovation (Bound 2008, 50). This is less common in tropical agro-industrial systems but examples of innovative locations in Brazil include the metropolitan regions of Campinas or São Paulo where multi-national agro-industrial firms interact with information technology clusters and leading universities. Additionally, there are quite different regions that center on Belem or Rio Branco in the Amazon in which niche producers in agro-forestry systems interface with global research networks and environmental services that are both traded and untraded.

Brasilia is a city that is better known as a seat of Brazil's head of state, but it too expresses agents of innovation that made this city into one of the greatest "hotspots" of patented tropical knowledge in the world. Across town from where Presidents da Silva and Morales met in 2007, the genetic resources and biotechnology labs (CENARGEN) of the globally-renowned Brazilian Agricultural Research Corporation (EMBRAPA) are the "home" base of three hundred technicians and doctoral-level scientists that specialize in cutting-edge aspects of tropical agro-industries. Professors in the University of Brasilia and other universities are frequent collaborators with CENARGEN researchers. Powerful agribusinesses, federal bureaucrats in the Ministry of Agriculture (MAPA) and grassroots environmental and indigenous networks all interact with scientists to shape and produce changes in agro-innovation in their own ways. Different permutations of interactions between agents of agro-innovation form within forty-six decentralized locations of EMBRAPA across Brazil that comprise nine thousand technicians and doctoral-level scientists. In each of these places, including the regions of Campinas or Belem that are described above, different mixes of agents of innovation in a particular institutional and ecological context help to explain key aspects of territorial processes of innovation in South American agro-industrial systems.

One question that remains under-explained in the literature on agro-innovation is how and why tropical agro-industrial systems form relationships to distant regions as part of the production of knowledge? Agents of innovation that base their work in subnational hotspots of innovation

within Brazil also produce knowledge through interactions with other regions, including regions across national borders. Since the turn of the century, scientists from the forty-six units of EMBRAPA, large agro-industrial firms and other heterogeneous agents of innovation from hotspots of knowledge within Brazil have begun to move in different ways to locations at more global scales. These multi-locational processes extend to traditional centers of global agricultural science in the United States and Europe but also to the world regions of Latin America and Africa that comprise different arrangements of tropical agro-industrial systems. which forms the spatial focus of this dissertation. The spatial focus of the present research is the world region of Latin America. What explains the geographical organization of agro-innovation that form between these locations of Brazil and varied locations within Latin America?

This dissertation argues that a matrix of inter-regional channels that connects to other locations produces knowledge that complements innovation in tropical agro-industrial systems at home in a given regional hotspot within Brazil. The three studies that form this project “mobilize” this learning matrix by examining agents that move from home regions in Brazil through “host” locations within Latin America, the world-region at the center of this research. The present dissertation argues that these multi-locational agents carve out new social relations to people and places in varied localized contexts within Latin America that provide bits of a wider spectrum of knowledge that spills over the boundaries between people and organizations into innovative processes within home regions within Brazil. This dissertation contributes a set of empirics within the conceptual framework of this learning matrix in order to explain the recent era of tropical agro-industrial systems as well as the trajectory of these incipient relational geographies into the future. In the context of globalizing agro-industrial systems, this research provides an important insight into the multi-locational dimension of knowledge and innovation in South American agro-industrial systems. By extension, these findings and framework contribute to great debates over the geography of agro-industrial organization, environmental conservation and multi-scalar governance in the global tropics into the future.

RESEARCH QUESTION

This dissertation asks the research question: how does the geography of multi-locational agents from Brazil to locations within Latin America explain innovation in tropical agro-industrial systems during the recent era of globalization and global climate change? Three sub-questions center on different multi-locational agents of agro-innovation from Brazil (university scientists, EMBRAPA scientists and large agro-industrial firms). These address different conceptual building blocks of the relations, absorption and governance of knowledge flows within this inter-regional matrix. The first level of analysis, in chapter two, asks how the mobility of university-based plant scientists contributed to knowledge flows at the level of two subnational agro-regions of South America in an era of agricultural modernization from 1900 until 1970. The second level of analysis, in chapter three, asks what explains the geography of mobile EMBRAPA scientists to Latin America since the turn of the century and the ways that this region helps to explain the global dimensions of agro-innovation within South American agro-industrial systems? The third level of analysis, in chapter four, asks where and how do Latin American branches of subsidiaries controlled by large Brazil-based agro-industrial firms explain recent geographical shifts in the organization of agro-industries, and what are the potential implications of these cross-border geographies for processes of learning?

This introduction proceeds in the following manner. The following section, titled “Explaining the Cross-Border Geography of Agro-Innovation,” briefly reviewing four sets of existing explanations of the relations of agro-innovation between Brazil and Latin America but argues that these do not fully address the processes under study in the present research. The second section, titled “Mobilizing an Inter-Regional Learning Matrix,” proposes an alternate conceptual framework of an inter-regional learning matrix that unifies the three studies of this work. The presentation of this framework includes: first, a discussion of four different scholarly debates on which this

framework is based; second, the definition of this concept and related sub-concepts and terms and; third, the design of this research. The third section of this introduction, titled “Contributions and Implications,” discusses the implications of this inter-regional dimension of knowledge and agro-innovation for three debates of great relevance for Brazilian regions and the tropical world more generally: the organization of agro-industries, the conservation of tropical environments, and the governance of multi-scalar knowledge communities.

LITERATURE REVIEW: EXPLAINING THE CROSS-BORDER GEOGRAPHY OF AGRO-INNOVATION FROM THE EMERGING ECONOMY OF BRAZIL

Policies and Politics of Technical Assistance in Agriculture

New literature on the Brazilian government as an ‘emerging donor’ of foreign aid put the mobility of EMBRAPA scientists to Latin America and Africa “on the map” over recent years through the lens of their consulting activities for technical assistance projects in agriculture. This literature primarily turned on debates over the Brazilian “interests” behind technical assistance, with initial studies suggesting that EMBRAPA-assisted projects were an expression of the solidarity of the government of Brazil to neighboring governments (Costa Vaz and Aoki Inoue 2007, Cabral and Weinstock 2010, Dusi 2012). More recent work, on the other hand, suggested that mobile EMBRAPA scientists were instruments of the soft power of Brazilian presidents and diplomats that sought to achieve national interests in arenas such as commercial agreements or global governance (Batista Barbosa 2012, Muggah and Passarelli Hamann 2012, Burges 2014). These studies provided new insights by situating mobile EMBRAPA scientists within policies and politics of foreign assistance that the Brazilian government provided to government in Latin America and Africa. What this literature did not address was the question of knowledge flows in

tropical agro-industries and the logics of agro-innovation that also shaped the activities of EMBRAPA scientists in Latin America and Africa, both within technical assistance projects as well through other types of connections in these world regions.

Internationalization of Multinational Agribusinesses from Brazil

A separate set of literatures on the internationalization of multinational agribusinesses from Brazil situated the mobility of scientists within the study of firms from Brazil that that were beginning to operate outside national borders. Analysts in the international business literature began to examine the determinants of internationalization of multinational firms from Brazil as part of firm-level decisions to internationalize activities to foreign countries (Spohr and Freitas Silveira 2012, Fleury, Leme Fleury, and Mendes Borini 2013). An agrarian political economy literature examined the power of multinational agribusinesses from Brazil to enlist the support of public organizations such as EMBRAPA in order to advance the internationalization of activities in Latin America and Africa, for example through the acquisition of land (Amanor 2013, Clements and Fernandes 2013, Scoones et al. 2016).[1] Analysts also began to consider firms from Brazil in terms of the land use impacts of multinational agribusinesses. These literatures help to explain the factors that influence the organization of multi-national agribusinesses these approaches normally operate at the spatial unit of nations, which does not fully address subnational and supranational geographies of such organizations nor the poly-centric processes that produce knowledge flows in tropical agro-industries

[1] However, as some analysts also note, the wider scientific portfolio of EMBRAPA is not reducible to agribusiness interests alone (Scoones et al. 2016, 6).

Agronomic Spillovers

Models of Agronomic Spillovers arose to explain germplasm transfer in the inter-national system of agricultural technology associated with the era of the “green revolution” (Alston et al. 2000, Alston 2002). These help to attribute innovation in Brazilian to different producers of biological innovations (Pardey et al. 2004). Analysts suggested that the global activities of EMBRAPA are explained by the spatial distribution of the composition of soils that suggest the lines of a spatial restructuring of systems of innovation at macro-regional scales in Latin America (Pardey, Wood, and Hertford 2010). These explanations, which are implicit in work on EMBRAPA in terms of the geography of the savannah biome at global scales in Latin America and in tropical regions of Africa, help to forecast the way that the current distribution of biological and ecological factors influence the geographies of the organization of research at scales both across nation-states in Latin America but these explanations cannot capture the contingent ways and scales through which innovations across different institutional contexts are produced.

Indicators of Foreign Scientific Collaborations

A small literature has begun to examine use knowledge and innovation metrics to examine aspects of international collaborations of scientists from Brazil (Leta, Thijs, and Glänzel 2013). Agricultural sciences and international collaborations are components of this research but there is almost not research that disaggregates the locations, organizations and nature of cross-border collaborations of Brazilian of agricultural and environmental scientists at any scale. The consultant report that Penteado Filho and Dias Avila conduct for EMBRAPA with bibliometric data from 1997 to 2006 is a rare example that examines foreign collaborations of agricultural scientists more closely, but this is primarily a benchmarking analysis for internal purposes rather than an explanation of global activities (Penteado Filho and Dias Avila 2009). This and other reports on

global collaborations of EMBRAPA scientists also focus on the virtual collaborations with foreign laboratories (Labex) in the United States, Europe and Asia rather than on the region of Latin America or Africa (Penteado Filho and Dias Avila 2009, Agropolis International 2012). The use of patent data to examine global aspects of innovation of regions within Brazil is largely unexplored beyond a handful of studies (Gonçalves and Almeida 2009, OECD 2015, 123-25). The explanatory framework in this dissertation responds to the call by Brazilian scholars of innovation for more theoretical explanation of the global geography of Brazilian scientists and innovation networks (Velho 2001, Yumi Ramos and Velho).

CONCEPTUAL FRAMEWORK: AN INTER-REGIONAL LEARNING MATRIX FOR TROPICAL AGRO-INNOVATION

This section discusses an alternate conceptual approach to the geography of tropical agro-innovation through the framework of an inter-regional matrix of learning channels to locations in Latin America that facilitates the flow of a more varied spectrum of knowledge into “hotspot” regions of innovation within Brazil. The first sub-section begins by discussing recent research and debates on mobility and the geography of knowledge that provide the foundations for this framework. The next sub-section defines the inter-regional matrix and other related concepts and sub-concepts that are addressed in the three studies of this dissertation. The third sub-section discusses research design that uses and constructs this approach.

Extending Research on Mobility and the Geography of Innovation to New Sites and Sectors

This matrix framework approaches innovation through a broader set of agro-industries by building on unsettled debates in economic geography over the extra-regional dimensions of regional systems of industries and services that thrive through spatial proximity.[2] Some analysts use "global pipelines" as the term for the structured nature of connections between distant locations that may be able to transmit certain more valuable partially-tacit dimension of knowledge into a given regional industrial cluster (Oinas and Malecki 2002, Simmie 2003, Bathelt, Malmberg, and Maskell 2004, 42, Boschma 2005, Gertler and Levitte 2005). Research on trade fairs and conventions also leads some scholars to suggest that temporary periods of co-location may be sources of learning from distant regions as well as a platform for the construction of knowledge networks (Boschma 2005, Maskell, Bathelt, and Malmberg 2006, Fontes, Videira, and Calapez 2013). These extra-regional dimensions of regional industrial systems may be particularly important to innovation in less central regions, such as those found in emerging economies, but limited research has been conducted in regions outside of North America and Europe (Poon, Hsu, and Jeongwook 2006, Rodríguez-Pose and Fitjar 2012).The present dissertation builds on this research in order to extend explanations of the geography of knowledge in agro-industries beyond dichotomous approaches to the mobility of codified knowledge in corporate agribusiness chains and the immobility of tacit knowledge within organic agricultural networks (Morgan and Murdoch 2000).

The present research on inter-regional channels of agro-industrial systems builds on new approaches to the mobility of knowledgeable individuals that differ from the traditional economic model of high-skilled migration as either a "brain drain" or a brain gain".[3] Saxenian, for example,

[2] Regional scholars of industrial systems emphasize spatial proximity as a central principle of tacit knowledge flows relevant for innovation.

[3] The present study extends research on mobility of high-skilled individuals has been conducted in Europe and there is limited research on the brain circulation of public research scientists from Brazil and Latin America, or with respect to tropical agro-industrial systems (Ackers 2005, Jonkers and Cruz-Castro 2013, Scellato, Franzoni, and Stephan 2015). Despite the importance of initiatives of the Brazilian government

proposes the concept of the ‘brain circulation’ of engineers and entrepreneurs between Asia and Silicon Valley as key vectors of partially tacit flows of knowledge and micro-level institutional changes (Saxenian 2006). Mobile knowledgeable individuals may form extra-local search networks that transmit partially-tacit knowledge that can then be applied to for the redesign of institutions and firms in the home or sending region (Saxenian and Sabel 2008, Solimano 2008, Filatotchev et al. 2011). Alesina et al also find empirical evidence that suggests that the mobility of high-skilled individuals increase rates of patents in host locations because institutional and social factors associated with places of birth shape different cognitive frames of problem-solving that are complements to the social production of innovations (Alesina, Harnoss, and Rapoport 2016, 119-120). The mobility of innovative agents developed through co-location within institutional contexts may also produce knowledge flows to previous locations inhabited by such agents (Agrawal, Cockburn, and McHale 2006, Fontes, Videira, and Calapez 2013). The present research extends research on these unsettled questions to new sectoral cases of agro-industries and sites of analysis in the tropics.

This framework approaches agro-industrial firms as drivers of changes in the geography of innovation by building on literature that suggests that multi-locational firms from emerging economies are associated with particular geographies of knowledge. Analysts suggest that agribusinesses from these regions may express different geographies of innovative activities but there is a need for more current and fine-grained evidence on these organizations (Rama and Martinez 2013). Analysts suggest that multi-locational firms from emerging economies more generally may express different locational strategies in comparison to counterparts from the United States because they acquire – rather than deploy – of knowledge and innovative capabilities from other locations, for example through subsidiary branches (Cazurra and

such as Science without Borders, which includes agricultural and environmental sciences, there is only a very limited literature on current questions of mobility of scientists and other highly-skilled actors from Brazil (Velho 2001, Roma de Castro and Silveira Porto , Yumi Ramos and Velho 2011, Roos et al. 2013).

Ramamurti 2014). Other analysts push this farther by beginning to examine the differences in the locational “filters” of firms from emerging economies at the unit of distant subnational regions as opposed to foreign nations. This research points to the need to understand multi-locational agribusiness in South American agro-industries as agents of innovation that are embedded in a broader range of territorial interactions across multiple locations than is commonly assumed (Craviotti 2016).

The inter-regional matrix approach integrates environmental dimensions of knowledge into a broader framework of tropical agro-innovation by building on two lines of ecological research: the first on “matrix ecology” and the second on the multi-locational dimension of social and knowledge-based drivers of land use change. The “matrix ecology” literature in which scholars develop a landscape-level conservation framework that focuses on the ecological quality of mixed-use tropical landscapes that includes agricultural areas (Perfecto, Vandermeer, and Wright 2009, Perfecto and Vandermeer 2010, Hecht 2014b). This framework offers an alternate more integrative framework through which to approach the contingent relationship between agricultural technology and land use in comparison to the traditional model that assumes that agricultural intensification in one unit of land use will spare discrete units of land use for the complete conservation of natures (Perfecto and Vandermeer 2010). These approaches provide a framework for the great variation in interactions between inextricably inter-connected agricultural and non-agricultural land uses in tropical territories (Kaimowitz and Angelsen 1998)The present framework builds on these approaches by transposing this ecological framework to a focus on the territorial systems of nature in surrounding areas that shaped varied sectoral systems of agro-industries. The matrix framework developed in the present study builds on a second line of debates on tropical land use conservation that incorporate multi-locational dimensions and agents into models of land use change within a given territory. These approaches are important to understanding changes in tropical agro-industrial systems in the context of globalization. Research suggests that “social” transmission of knowledge associated with mobile agents from tropical agro-regions may

shape institutional innovations related to the incorporation of environmental considerations into crop cultivation approaches (Hecht and Saatchi 2007, Hecht 2010, Hecht et al. 2015).

This dissertation develops the concept of an inter-regional learning matrix as an analytical framework of the spatial and social processes through which mobility feeds knowledge from varied "surrounding" regions within Latin America into subnational locations of innovation in tropical agro-industrial systems within Brazil. An *inter-regional learning matrix* is the more specific term for the set of inter-regional social channels through which a subnational location absorbs knowledge from other subnational regions as part of innovative processes in tropical agro-industrial systems in the recent era of globalization and global climate change. This matrix represents a more particular version of a *regional system of circulation*, the general term for the relational-institutional arrangements of agro-innovation through which tropical regions learn over time from other territories through the outward and inward mobility of agents, knowledge and material technologies. This matrix forms through a social, historical and spatial production of a patterned but shifts set of place-to-place processes as well as the governance between innovative agents. The matrix expresses a network structure but differs from a more common usage of network by emphasizing the social relations and quality of learning of this network (Latour).

A matrix is comprised of *learning channels* to other subnational regions. A learning channel can be understood here as an open relational-institutional space of knowledge flows between different subnational territories, both within and across nation-states. A channel is a connection between a single subnational region and another subnational region, irrespective of whether it lies within a particular country or in a contiguous or non-contiguous foreign country. This dissertation focuses only on the inter-regional channels of each respective matrix that form only to other subnational regions in Latin America. although other inter-regional channels to domestic and global regions beyond the scope of these three studies also form this matrix. Learning refers to the absorption, sharing and application of knowledge from another subnational region through interactions with place and peoples. This is produced through social processes associated with multi-locational agents and their governance processes in conjunction with other heterogeneous

innovative agents, both mobile and less mobile.[4] The term mechanism of learning refers to the learning processes associated with the mobility of a single mobile agent. A channel is the general term for an inter-regional connection that comprises learning and will vary according to the governance of relations between mobile agents as well as through the relations of mobile agents to other agents of innovation between two given locations. A channel is a relational-institutional space that forms through multi-locational agents that produce learning channels and, by extension, the matrix.

Mobility is a process that forms the channels of the matrix. This dissertation examines the *mobility* of agents of innovation as one of the key causal social processes that constitute and continually re-produce this matrix. The social aspect of learning processes in this matrix distinguished flows of knowledge from the material dimension of trade in product technologies or the physical transfer of knowledge through computer networks. The term learning is used here in a similar way to knowledge flows, but emphasizes the social nature of knowledge flows. The term knowledge spill-ins refers broadly to knowledge that passes boundaries – between agents, organizations and spatial units - in the more expansive sense of the term as used in economic geography and science and technology studies to refer to a wider spectrum of informal knowledge flows.[5] Multi-locational agents of agro-innovation comprise a heterogeneous set of knowledgeable individuals as well as organizations that move physically beyond their home region as part of work or other practices that influence agro-innovation. This study examines the mobility of EMBRAPA scientists and the branch organizations of large agro-industrial firms that are based in Brazil. as two cases of a larger heterogeneous set of agents that can be defined in a similar way the literature on regional systems of agricultural innovation.

[4] The production of knowledge and innovation is a complex and non-linear process shaped by institutionally-embedded and networked agents of innovation.

[5] This contrasts with a more restrictive sense of the term as the unaccounted-for knowledge that passes outside of a contract between economic agents or, alternatively, the usage of spillovers in terms of forecasting potential for inter-organizational or inter-national transfers in the agronomic models of agricultural economists.

Research Design and Methods

The key to explaining the conditions under which such processes of mobility shape knowledge flows and institutional contexts relevant to innovation in agriculture and forests is a finer-grained understanding of the modalities, specializations, locations and nature of the mobility of public sector scientists and agro-industrial firms from Brazil. This research builds the matrix up from the ground by "following" processes of mobility and learning across multiple locations that produce this matrix in Brazil and Latin America through evidence from qualitative fieldwork and primary historical sources, quantitative and categorical sets of data, and related policy and planning documents. This approach to the situated nature of innovation in agricultural sectors and the way that this is linked to different places is an established technique, particularly so as part of attempts to ground analysis of processes of "globalization" by, for example, following scientists in order to understand the networks through which scientific actors operate across scales and the ways that this helps to explain spatial flows of knowledge across places (Latour 1987, Ekboir 2003). The use of case studies and qualitative research is an established approach in regional systems of agricultural innovation for analysis of heterogeneous actors and institutional arrangements that shape agricultural innovation in particular places, and have been used to explain the emerging role of actors from EMBRAPA as part of heterogeneous sets of actors at subnational scales. This approach is important to analyze processes of innovation in resource sectors as well as in economies in which patenting activity is not a sufficient indicator of innovation (Anlló et al. 2010).

This study is based on evidence from 105 semi-structured interviews with agricultural scientists from EMBRAPA and INIAF involved in these projects as well as networks of administrators, diplomats, government ministers, private sector associations, multilateral organizations, academics as actors and civil society policy actors involved in technical cooperation and economic relations more generally in Brazil, Bolivia and in El Salvador. Interviews followed processes across different space and actors that operate in different arenas and locations rather

than a thick ethnographic research on, for example, scientists in a particular place. This research sought to examine the way that these questions of agricultural innovation were located in larger processes of technical cooperation and economic relations between the two countries. Interviews also served a source of access to non-public data that could not have been obtained through other methods without the personal rapport established through face-to-face contact and trust established through the interview process.

This study used novel strategies to construct aggregate datasets at the level of the world region of Latin America from more granular units of analysis of agents, locations, and knowledge and sectoral types. This dissertation constructs new evidence on these processes across multiple sites in Bolivia and Latin America. Chapter two uses new dataset on the mobility of agricultural scientists from across Latin America since the 1940s for the purposes of education and training from historical records. This study also builds a new dataset on the mobility of scientists from EMBRAPA through a scraping of data from the national government record on the travels of scientists from EMBRAPA. The construction of these data sets situates existing case studies in broader trends as the basis for theorization, as well as to serve as a source of separate richer case study analyses of particular aspects of these processes

This study also relies on policy and planning documents. These include projects documents, internal reviews and monitoring and evaluation reports from an array of government organizations in Brazil, Bolivia, the wider Latin America region, the United States and Europe, as well as multilateral organizations such as the World Bank and the Inter-American Development Bank. This grey literature is a primary source of evidence that the historical analysis of Chapter 2 uses to reframe processes of mobility of agricultural scientists from Latin America. In Chapters 3 and 4, content review of published policy and planning documents provides evidence that triangulates with interview data and quantitative data.

CONTRIBUTIONS AND IMPLICATIONS

This framework and set of empirics for understanding knowledge flows in nature-based industries has implications for debates over the future geographies of economic organization, environmental conservation and governance interventions across the global tropics. The framework and empirics developed for understanding recent processes is important for the uncertainty of changes in technologies, climates and policies that shape these questions. This study also has predictive implications at a moment of uncertainty on the directions of technological change in agriculture in the context of climate change as experts are seeking to build better forecasts of the role of Brazil and Latin America in future pathways of innovation and environmental change (Pardey, Wood, and Hertford 2010, Torres, Kanadani Campos, and G. 2013).

Organization of Tropical Agro-Industries

This study of the geography of innovation is important for understanding changes in the organization of tropical agro-industries (Fuck and Bonacelli 2010, Rama and Martinez 2013). This study goes beyond existing explanations and empirics based on more static frameworks based on research and development (R&D) units of public research institutes or agro-industrial firms (Lee and Walsh 2016). This study of wider agents of innovation across space addresses product, process and institutional innovations that are a key factor in changes in both agro-industrial organization at more global scales. The current study of powerful global agro-industrial firms such as JBS that reshapes questions of innovation through locational strategies and acquisitions at global scales, represents an important contribution to poorly understood processes through which issues of innovation are part of agro-industries restructuring as well as related sectors such as

agricultural information technology that form as part of the global production networks of these lead firms (Wilkinson 2009, Rama and Martinez 2013).

Conservation of Tropical Natures

The findings of this regional study from Latin America, the world region that possesses among the world's most lucrative and expandable agro-industries frontiers as well as nearly one quarter of global forests, therefore serve as harbingers of changes at more global scales. This study of the matrix of knowledge flows informs important debates over land uses of agro-industries as well as for competing uses such as for tropical forests, primarily based on site-based studies. This examination of public sector scientist and agro-industries firms as agents of knowledge and innovation provides insight into changes in tropical sciences, which were factors in declining rates of deforestation in Latin America over an era of booming agricultural commodities markets (Hecht 2014a). The answers to these questions lies in improving our understanding of the more localized ways that global agro-industries and projections of land use change manifest in different ways across the varied agricultural production systems and variable impacts of climate change within Latin America. This research drills down into the locations, organization and specialization of agents of innovation from Brazil in order to respond to the call for finer-grained analysis of how and why pathways innovation and environmental change form between heterogeneous but inter-connected locations (Ely and Scoones , Leach et al. 2012). This finer-grain of data improves our ability to explain the non-linear way that agents of knowledge and innovation both influence and manifest across the different innovative milieu produced by heterogeneous local institutional arrangements, tenure regimes, agronomic characteristics, local politics, and different arrangements of heterogeneous local actors across Latin America. This study of public sector scientists from Brazil, a country which possess regionally-differentiated agricultural production systems and nearly half a billion hectares of forests across multiple biomes, to Bolivia, which

possesses a related but distinct arrangements of intellectual property regimes, tenure regimes, indigenous politics and smallholder agro-industries frontiers, holds insights for explanations of EMBRAPA as a model and consultant across other more differentiated contexts in places such as Cuba and Mozambique. These ground-up findings on incipient processes of agents of innovation on the ground and across borders contributes important insights to our explanatory models of systems of agricultural and forestry innovation at a moment of considerable uncertainty on global-scale transformations in agro-industries systems and the land use drivers of climate change.

Governance of Innovation at Multiple Scales

This study has implications for the governance of multi-locational processes that influence innovation, both in tropical agro-industries as well as across a broader set of sectors. As Saxenian and Sabel suggest, the mobility of knowledgeable individuals from emerging economies may contribute to innovation through the construction of “shared, domain-specific understandings and languages (or interpretations)” that allow agents to “search for new models of products and of organizing production, even in distant localities, and to collaborate in incorporating these new possibilities into existing practices” (Saxenian and Sabel 2008, 392, Sabel and Zeitlin 2011). The present studies of key agents across inter-regional channels into new sites within Latin America thus has implications for the potential integration of “communities” - of epistemes, practices and knowledge - that appear to remain partially-fragmented across distant locations (Coe and Bunnell 2003). This framework provides insight into episodes of mobility as an iterative and recursive process that integrates more localized communities into diverse but related varieties of epistemes of tropical knowledge across sites (Cohendet et al. 2014, Benner and Pastor 2016). These insights may be particularly significant since these may form the basis for new dimensions of resilience based on institutionalized interactions between diverse communities across space(Benner and Pastor 2016).

ORGANIZATION OF DISSERTATION

This dissertation is organized as three papers that analyze distinct dimensions of an inter-regional matrix of learning, followed by a concluding chapter. The dissertation format of three papers builds a more granular understanding of select foundations of this larger explanatory framework. The analytical entry point of each of the three empirical chapters is a different types of mobile agent from Brazil. Individual university scientists are the focus of chapter two, individual public sector scientists in chapter three, and subsidiary branch organizations of agro-industrial firms in chapter four. The organization and focus of the four remaining chapters is discussed below.

Chapter 2, titled “Running Roots of Tropical Agro-Regions” unearths the deep historical roots of inter-regional learning in a key era of agricultural modernization from 1900 to 1970 that long preceded the more recent period that forms the basis for the particular matrix concept. This paper develops the general concept of a regional circulatory system to explain the territorial variation in arrangements of extra-regional learning across different eras and tropical agro-regions within South America. This paper compares systems of circulation across the two subnational regions of Minas Gerais, Brazil and Cochabamba, Bolivia that were the home of mobile plant scientists from nascent agricultural universities. The argument of this chapter is that mobility emerged from different agro-regions within South American in the context of modernization but suggests that differences in the ways that systems of innovation in these two regions incorporated the knowledge of mobile scientists from nascent agricultural universities helps to explain different capabilities for agricultural innovation across the two cases. This regional basis of explanation of innovative capabilities revises the organizational basis of EMBRAPA’s success in agricultural innovation in Brazil and also contributes new perspectives on the varieties of processes through which territories in Latin America molded, shaped and leveraged knowledge flows for territorial

processes of development in ways that undercut more monolithic explanations of the so-called Green Revolution in Latin America.

Chapter three, titled “Moving to Peripheral Fields of Agro-Innovation” examines the changing geographies of public sector scientists from Brazil as a factor in the production of knowledge and innovation in Bolivia and Latin America over the last decade. One entry point into this mobility was a modest agreement for scientific and technical cooperation that the agricultural ministers signed in the shadow of the main negotiations in 2007 between Presidents da Silva and Morales that involved visits of EMBRAPA scientists to locations in Bolivia as part of a modest consulting project to scientific and administrative representatives of the Bolivian government on the organization of agricultural innovation in that country. This study begins by using indicators on patents and publications to examine the location and specialization of scientists from EMBRAPA as agents of knowledge and innovation in Bolivia as well as more broadly in Latin America. The findings of this chapter are based on semi-structured interviews with scientists from Brazil and Bolivia that were involved in these projects as well as the broader networks of relations that built up around this case. This research examined the location, specialization and organization of processes of mobility from EMBRAPA between 1990 and 2015. This process demonstrates the increasing importance of mobility and examines these processes in order to explain the mechanisms through which these shape the production of agricultural learning, knowledge and innovation in Latin America. This chapter suggest the ways in which otherwise “peripheral” agricultural frontiers function in tandem with other processes of scientific mobility at the “technological” frontiers of agricultural innovation, for example through research through the Labex projects and other emerging areas of environmental, technological and biotechnological research.

Chapter four, titled “Beyond the Fence of the Brazilian Farm,” lays the empirical and conceptual basis for a new approach to branches of subsidiaries of multi-locational firms from Brazil as a source of inter-regional learning in the matrix of a given “home” regions within Brazil. This chapter constructs and analyzes a novel new dataset that provides the first disaggregated view of the location, organization and specialization of branches in Latin America of large agro-

industrial firms that are based in Brazil in the year 2013. A more granular evidence of “globalizing agro-industries” helps to construct the actual sectors downstream of the farm, commodities of meats and grains, and locations within South America that cross borders into Latin America. These activities are uneven processes that cluster within the Southern Cone. These processes center on red meats production chains and sectors downstream from primary production on the farm. This chapter suggests the way that these agents operate as part of changes in agricultural innovation, for example in the Southern Cone region in Uruguay are part of broader processes of regionalization of agro-industries production systems. This chapter also discusses the implications of these patterns for explanations of large firms from Brazil as causes of agro-industrial and land-based change as well as the ways that these new cases may diverge from existing explanations of restructuring based on firms from other locations and in previous eras.

Chapter five concludes by interpreting the findings on mobility and the inter-regional learning matrix in light of uncertain future trajectories of agro-industries, land use change and the governance of mobility from locations within Brazil. This discussion addresses the current uncertainty and possible future inflection points of the emerging economies into the future after the previous decade of growth of Brazil and these economies. This examines the scholarly implications of these findings as part of the creation of a broader research agenda that unifies and deepens the study of the mobility of agents of knowledge and innovation from the emerging economies as part of broader global-scale processes in the source and location of economic growth and climate change. This chapter suggests recommendations for policies in Latin America since 2000 and lays the basis for future research on additional dimensions of this matrix.

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Chapter Two. Running Roots of Tropical Agro-Regions: Mobile Plant Scientists and Agricultural Modernization in South America, 1900-1970

INTRODUCTION

Forward-looking debates over the future of agricultural innovation across the global tropics have begun to glance backwards for historical lessons from the formation of agro-industries in Brazil (Eicher 2006, Correa and Schmidt 2014, Figueiredo 2014). One example that some specialists use to explain how Brazil "got it right" in agricultural innovation and "out-farmed the American farmer" was the decision in the early 1970s by the Brazilian Agricultural Research Corporation (EMBRAPA), a public research institute specialized in tropical agriculture, to send agronomists to obtain graduate education in the United States (Hecht and Mann 2008, Correa and Schmidt 2014). This example is important but it is also begs a more general examination of why and how the spatial mobility of agricultural scientists from an expanded set of locations in Brazil and South America contributed to socio-technological changes in the tropics. The literature contains passing references to foreign training of "local" plant scientists, for example, agronomists from Mexico in the context of "green revolution" projects in agricultural technology after the 1940s, but no research exists that specifically addresses the question of the spatial mobility of plant scientists from Latin America (Fosdick 1989, 188). The present paper addresses this gap by using published memoirs, primary sources and technical reports on processes of mobility from two subnational regions of tropical agriculture in South America from 1900 to 1970 in order to conceptualize mobility and build an explanatory framework of how this influenced outcomes of learning at the regional level.

Debates over mobile scientists in agricultural modernization schemes in tropical agriculture rotate around the axis of a handful of “grand missions” by Rockefeller Foundation officers and corn belt agronomists that traveled to locations in northern Mexico to spearhead the development of ‘green revolution’ technological packages for hybrid crop varieties beginning in 1943 (Cullather 2010, Wright 2012, Patel 2013).[1] However, a select but growing cadre of plant scientists from Latin America also conducted pioneering long-distance trips associated with agricultural technology to locations in the United States and elsewhere beginning in the early twentieth century as part of agricultural modernization schemes that centered on higher education in agriculture as an alternative to redistributive agrarian reform. What were the “missions” of these travelers from the tropics and what did they learn? How did the relational-institutional arrangements of these local cadres within and between the political-ecological setting of ‘home’ and ‘host’ locations mediate the ways that tropical regions learned from distant knowledge? The present study of the mobility of plant scientists in two regional histories that center on the universities in the Brazilian state of Minas Gerais and the Bolivian state of Cochabamba during a critical juncture in the formation of systems of innovation can help to begin to parse the ways that mobility shaped regional outcomes of learning.

In 1936, more than three decades before the founding of national research institutes such as EMBRAPA, Antônio Secundino de São José, an agronomist at the recently-established Higher School of Agriculture of Viçosa (ESAV) in the ‘forest zone’ of Minas Gerais traveled to locations in the southern and midwestern regions of the United States at approximately the same moment as Martín Cárdenas, a tropical botanist from the inter-Andean valleys of Cochabamba, also headed north to locations in northeastern region of New England. The Brazilian economist Ana Célia Castro wove this trip of São José into her case study of the innovative hybrid corn firm that he founded in Minas after returning from the United States. We can also expand on these references

[1] The standard example is Norman Borlaug, an agricultural scientist from the upper Midwest region of the United States that was a scientific consultant to Rockefeller Foundation agricultural technology projects in the tropics.

by examining primary and secondary accounts from this and other missions of both São José and Martín Cárdenas as entry points through which to examine wider regional outcomes of learning from mobile plant scientists over time in Minas and Cochabamba (Castro 1988)?[2] We know that both São José as well as Cárdenas would go on to lead distinguished careers but by the mid-1960s at a critical juncture that preceded the founding of EMBRAPA as well as the counterpart national institute of agricultural technology in Bolivia (IBTA), analysts regard Minas as a successful regional system of agricultural innovation in comparison to the Cochabamba case in which agricultural innovation was considered to be lackluster (Herranz-Loncán and Peres-Cajías 2015). This research poses the question of how the mobility of plants scientists from Minas and Cochabamba contributed to regional outcomes of learning by the mid-1960s and uses insights from this particular case to construct a framework of regional historical processes of scientific mobility from South America as a factor in socio-technological change in tropical agricultural regions more generally.

Theories of the global diffusion of Western science, public investment in innovation, and planning for scientific manpower provide default conceptual models of the mobility of tropical scientists but these are not sufficient to explain the complex human geographies through which mobile plant scientists from Minas and Cochabamba shaped regional outcomes of learning over time. Models developed during the high era of modernization viewed the mobility of scientists from the developing world as a straightforward importation of formal principles of science as part of a mechanistic stage-based model of the diffusion of science from United States and Europe around the globe (Basalla 1967). The standard linear model of innovation in terms of the input of public investment into a public research organization or a state provide a partial explanation of differences in agricultural universities between Minas and Cochabamba but these are partial and the inability to disaggregate the particular questions surrounding mobility means that these are a poor indicator for mobility. Policy approaches to manpower planning from the Latin American era

[2] Hereafter this article uses the shorthand of Minas to refer to Minas Gerais.

of the founding of national research organizations – such as EMBRAPA and IBTA in the 1970s - provide a supply-demand model of the mobility of agricultural scientists based on short-term demands for organizations that outstrip the supply from “local” universities (TCA 1958, Cornehls 1968). The problem with these existing frameworks is the conceptualization of mobility as a discrete event rather than a continuous remaking of geographies of extra-local human mobility across space and time from South America, the bounding of the causal effects of scientific mobility to the import of formal scientific principles or graduate degrees, and the stripping of social relations and locational environments as mediators of technological change.

The present paper proposes an alternate framework of *regional circulatory systems* in order to re-conceptualize the extra-local mobility of plant scientists from the tropics as a component of a regional “system” of historically- and socially-constructed processes of multi-dimensional learning at global scales that mediates spillovers of extra-local knowledge. This framework builds intersections between literature on place-based regional systems of agricultural innovation and a separate literature on the spatial circulation of individuals from the developing world as a factor in global geographies of knowledge exchange (Saxenian 2005, Spielman 2005, Raj 2013). The general argument of this paper is that mobile plant scientists from both Minas and Cochabamba engaged in circulatory processes of multi-dimensional learning but differences in the regional governance of returning individuals over time formed capabilities to learn from extra-local knowledge in the case of Minas but not in Cochabamba. This research found that multi-dimensional social learning by scientists such as São José, Cárdenas and their fellow protégés shaped local projects of agricultural modernization in Latin America to a greater extent than previously understood but that there is a need to look beyond official visions for “foreign models” by embedding learning in the relations through which scientists from a particular location formed inter-regional channels to different places and the types of socio-technological and socio-environmental knowledge that this transmitted to home regions. These individual missions co-evolved with differences in the inter-organizational governance of extra-local learning, with denser coordination between elites in Minas in contrast to organizational enclaves in Cochabamba that

were less resilient to the broader political-economic shifts in the late 1950s and early 1960s. These comparative findings revise explanations of the contribution of scientific mobility to agricultural innovation in South America by emphasizing the historical and relational construction of learning from mobility at the regional level.

This paper proceeds by reviewing existing explanatory models before proposing an alternate framework of circulatory systems of tropical agricultural innovation and discussing research design. The first empirical section “roots” the mobility of plant scientists from Minas and Cochabamba in long-run historical processes of mobile knowledgeable individuals from the tropics and then presents the first aggregate estimates of the mobility of agricultural scientists from South America from 1930 to 1970. The second section uses evidence from the modernizing missions of São José and Cárdenas in order to examine the relational geographies and build a basic typology of learning that these expressed. The third section moves from the unit of missions to compare the inter-relational patterns and inter-organizational coordination that shaped regional governance of learning in *circulatory systems* associated with regional extension, education and innovation projects during the critical juncture from 1945 to 1960 in Minas and Cochabamba as part of a historical formation of regional capabilities to learn from extra-local knowledge.

EXPLAINING SCIENTIFIC MOBILITY FROM TROPICAL AGRICULTURE

The literature contains scattered comments on long-distance missions of plant scientists from different locations in South America during the era under study but no research has used evidence from these cases to explain the mobility of knowledgeable individuals as a more general factor in changes to tropical agriculture. Analysts suggest that scientific mobility in the EMBRAPA case in the early 1970s contributed to positive outcomes in scientific capacity, social capital and

institutions of technological upgrading but no studies other than technical reports have closely examined the particular question of mobility (Castro 2010, Correa and Schmidt 2014, 7, Figueiredo 2014, 16-17, 28). Interview-based evidence collected by economist Ana Célia Castro on the mobility of São José from Minas to the United States in the 1930s as part of her study of his firm Agroceres provides a point of departure for the present study which parses the more specific question of mobility at the regional level by using this primary evidence to build a comparison to the Cochabamba case (Castro 1988, Gu et al. 2012). Literature on São José is representative of a handful of works in which analysts discuss mobility as part of the development of plant sciences in South America but the lack of a causal framework for the particular factor of mobility within these personal biographies and regional histories make it difficult to extract more general insights beyond these single cases (Cotter 2003, Vessuri 2014).[3] The comparative approach to environmental history that McCook uses to problematize monolithic explanations of the development of agronomic and botanical sciences in Latin America during this era is instructive but the present study addresses a more specific question of mobility at the regional level as opposed to the larger question of agricultural modernization at the unit of the nation (McCook 2002).

Diffusion of Science to the Periphery

In contrast to the single cases discussed above, high-modernist models of the global diffusion of modern science from the United States and Europe conceptualize scientific mobility

[3]The work of Castro is based on interviews with São José but other analysts discuss this trip and the corn germplasm that São José brought back to Minas as part of firm-level technological strategies (Stal 1993), the role of the university in agricultural research (Sigueyuki Sediyama et al. 2012, 124), the diffusion of the concept of agribusiness from the United States to Brazil (Grynszpan 2008, 2012) and the upgrading of the agrifood sector in developing economies (Gu et al. 2012, 274, footnotes 34-35). Brazilian historians also discuss the Minas case (Mosher and Schultz 1955, Ribeiro and Wharton Jr. 1969, Ribeiro 2000, da Silva) as well as the agricultural university at Viçosa (Marcelo Ribeiro , Marcelo Ribeiro and Porfírio , Valentim da Silva).

from the global periphery as a mechanism of the transfer of formal principles of scientific knowledge during one stage of a linear process of global diffusion (Basalla 1967). Applying this model to the plant sciences suggests that mobile scientists such as São José and Cárdenas that studied in the "West" acquired narrow types of knowledge of formal principles of agricultural sciences but not the social knowledge or advanced technologies that scientists in the centers of the United States and Europe traded in informal groups. However, models of mobile scientists as mechanisms of diffusion cannot explain the social relations of mobility that allowed these agents from the tropics to return to Minas with advanced material technologies or insider knowledge from groups of scientists and private firms in distant locations. Additionally, the temporal approach to scientific mobility as a discrete transitional moment of external connection does not fit the evidence that mobility in Minas and Cochabamba evolved over a longer span of time that expressed non-linear trends in scientific capacity and complex geographies of knowledge exchange.

Organizational Plans for Scientific Manpower

At another level of analysis, policy literature on *scientific manpower* in agricultural research organizations provides the primary sectoral framework of the mobility of agricultural scientists from South America in terms of public sector planning for the foreign education of scientists to meet short-term human resource demands that outstrip the supply provided by local universities. A foreign aid version of this approach was based on "participant training" of "local" scientists that worked in early foreign aid interventions such as the Inter-American Agricultural Service (SAI) organization in Bolivia (ICA 1958, Bennell and Zuidema 1988, Abe 1989, Brush 1993). A national institutes of agricultural research version focused on the national capacity to plan for scientific manpower by sending scientists abroad to complete training in the United States for new public sector research organizations such as EMBRAPA (Alves 1983, Borges Andrade 1985, Quirino

1989, Borges Andrade and Oliveira-Castro 1996, Alves, Silva, and Fonseca Filho 2005). These approaches suggest that organizational factors such as the capacity of government planners or the legal-bureaucratic autonomy of research organizations can explain differences in scientific mobility between Minas and Cochabamba. However, the way in which these approaches conceptualize learning as a process at the unit of organizations falsely isolates missions from the wider territorial system of innovation and are unable to explain the ways that learning evolved at a regional level through relations between different agents and organizations within a system.

Investment in Absorptive Capacity

Literature that develops the concept of absorptive capacity helps to focus analysis on the way that an existing knowledge base may influence the ability of non-movers in tropical regions to acquire, absorb and apply knowledge from mobile “local” scientists (Cohen and Levinthal 1990). In this view, prior knowledge in Minas or Cochabamba may shape different absorption of knowledge acquired by mobile scientists such as São José or Cárdenas. However, the most common operationalization of this concept is a linear model of innovation in which public investment in scientific capacity improves the human capital base and, by extension, the absorption of extra-local knowledge. In this view, differences in public investment between the two universities in Minas and Cochabamba may help to explain differences in the ability of non-movers in the two cases to learn from extra-local knowledge. Another limitation of this literature is the conceptualization of absorptive capacity at the unit of the organization in ways that cannot explain differences that result from interactions between organizations or agents with a system. Investment-based explanation of innovation as well as the subset of literature on absorptive capacity help to explain part of the difference between the formation of the different regional systems of innovation. However, there are other sources of variation in processes of scientific

mobility that these theories cannot explain and which are not visible through national-level data on investment or formal education.

Regional Circulatory Systems of Agricultural Innovation

This paper proposes regional circulatory systems of agricultural innovation as an alternate framework that conceptualizes the spatial circulation of agricultural scientists such as São José and Cárdenas as a relational mechanism through which territorial systems of agricultural innovation such as those in Minas and Cochabamba learn from distant knowledge. A *regional system of circulation* is defined as the relational-institutional arrangements of agro- innovation through which tropical territories learn from other regions through the inward and outward mobility of agents, knowledge and material technologies. This extends basic tenets of systems approaches - such as non-linearity of innovation processes, heterogeneity and inter-relationality of innovative agents and organizations, and institutional embeddedness of knowledge production – to the scales of processes through which territorial systems such as those in Minas and Cochabamba learned from mobile scientists and other agents from the respective system (Nelson 1993, Spielman et al. 2008). Circulatory approaches in economic geography can be combined fruitfully with the systems approaches on education and training by conceptualizing knowledgeable individuals from the developing world as a source of complex, multi-dimensional and contingent processes of learning that encompassed more varied types of learning such as partially tacit scientific as well as institutional knowledge (Saxenian 2006). This framework also integrates mobile scientists from the tropics into approaches in history, historical geography and science studies that use the concept of circulation as part of global and transnational histories of material exchanges of agricultural knowledge (Fan 2012).[4]

[4] For example, transnational histories of the Green Revolution and those that look from south-to-north from Mexico to the United States conceptualize knowledge exchanges as more complex and multi-directional

In this framework, the *mission* represents an individual episode of mobile learning that expresses varied relations with sets of localized actors such as politicians, administrators and firms as well as non-local actors such as scientists, mobility-facilitating organizations, and business from locations at multiple scales.[5] These *missions* and the ways that individuals and organizations coordinate learning through the mobility of local actors are key processes that form a regional circulatory system. The relations of governance through which organizations and agents within Minas and Cochabamba coordinate wider processes of learning beyond the unit of the organizations is a differentiating factor between the two cases in the present study. This paper examines the ways that territories learn from extra-local knowledge over time as a source of variation in their *capabilities,* defined as the prior abilities of agents and organizations, to learn from extra-local knowledge as part of innovative processes.

Research Design

This study uses historical evidence to explain the extra-local mobility of agricultural scientists from South America as a cause of social learning between agents and organizations across two *circulatory systems* that center on the subnational states of Minas Gerais, Brazil and Cochabamba, Bolivia between the years 1900 and 1970 (Castro 1988). The study uses a 'follow-the scientist' methodology to examine the mobility of plant scientists through individual cases of Antônio Secundino de São José from Minas and Martín Cárdenas from Cochabamba in the 1930s and to work outward to explore regional systems of circulation as an inter-relational governance of learning between actors and organizations at multiple scales (Latour 1987, McCook 2002, 2013). Sources of evidence included primary accounts by mobile agents and their relations from

(Cotter 2003, Olsson 2013). There is a small literature on the circulation of scientists from Brazil, including the classic work by Schwartzmann in addition to other works that center on the 1950s (Schwartzman 1991, Almeida 2004).

[5] Latour's discussion of the embeddedness of scientists is instructive (Latour 1987).

autobiographies and unexamined correspondence, reports and other published and unpublished sources; period reports and documents of governments, philanthropies and consultancies involved with mobility of scientists from these regions as well as synthesis of discussions of mobility in secondary sources.[6] This study examined the relations of mobile scientists to public and private sectors at two levels, individual missions as well as circulatory systems, in order to explain the factors that shaped learning in these two regional cases (McCook 2002). New aggregate empirics on mobility of agricultural scientists from South America from internal reports of governments, philanthropies and consultancies situate these cases within a wider set of regional processes in locations within South America.

ROOTED MOBILITITIES AND AGRICULTURAL MODERNIZATION IN SOUTH AMERICA

Over the course of history, knowledgeable individuals from sites of tropical agriculture across Latin America have engaged in mobility to distant locations in the process of remaking agriculture at 'home'. Yet we know little about these individual pioneers and the collective processes of human mobility that knit locations in Latin America into complex geographies of knowledge exchange and production that changed tropical agricultures. This section situates the paths of human mobility from tropical agricultures in a longer historical timespan and then places the cases of Minas, Gerais and Cochabamba, Bolivia within aggregate empirics of mobility in

[6] The lack of an established tradition of biographies and autobiographies of scientists from Latin America limits the source material of scientific travelers from the tropics in comparison to counterparts from Europe and the United States and Europe that traveled to the tropics (Pratt 1992, Glick 1995, 882). This study utilized a variety of sources, including published memoirs and writings of Cárdenas and Gandarillas as well as unpublished and unpublished references to mobility from the personal papers of Rolfs from Minas, primary and secondary sources on mobility in an array of policy and planning reports, in addition to theses written by mobile scientists. Aggregate data on mobility episodes also reconstructed the circulation of scientists through a variety of administrative reports (Jöns 2008). Other analysts use and discusses historical evidence of elite Latin American travelers, see Farrell's discussion of historical sources of evidence of travelers from the America to the United States in the 18th and 19th centuries (Núñez 1980, Núñez 1989, Farrell 2015)

agricultural sciences from South America between the years 1930 and 1970. Long before 1492, diverse patterns of human mobility among indigenous groups formed in complex relation to crop and landscape-based technological systems in South America (Hecht and Posey 1989, Denevan 2001). Extra-local circulatory trekking, inter-regional exchanges and long distance trade and communication comprise some of the multi-locational processes through which individuals and societies shaped the development, distribution and diversity of plants and knowledge (Hofman and Hoogland , Denevan 1990, Kelly 1992, Hornborg 2005, Heckenberger 2006, Alexiades 2009, Snead, Erickson, and Darling). For example, crop-based evidence from arrowroot, chili peppers, manioc and peanuts between the Andes and Amazon suggest social exchanges of knowledge that scholars are working to understand through intermediary groups at the intersection of distant locations (Pearsall , Lathrap 1973, Perry et al. 2006, Dudley). There are more challenges to understanding inter-regional connections where agricultural systems were based on 'soft' or landscape-based technologies but frameworks that conceptualize the circulation of people and social knowledge alongside material technologies provides insight into the ways that these processes produced agricultures as well as natures more generally (Hecht and Posey 1989, Erickson 2003).

Localized Knowledge on the Move during Colonial Botanical Exchanges

Analysts of colonial plant exchanges have begun to re-cast the importance of knowledgeable individuals from Latin America in the co-production of agricultural knowledge but the multi-local nature of such individuals during this era remains largely unexplored (Cañizares-Esguerra 2004, b, Deans-Smith 2006). An exception is Figueroa and Silva, who theorize mobile naturalist scientists from Brazil as a pragmatic and eclectic search for scientific knowledge across locations in Europe through the appropriation, amalgamation and employment of varied scientific traditions as opposed to simple importation from elsewhere (Figuerôa and da Silva 2000).

Colonial-era networks of botanical gardens and expeditions also shaped cases of long-distance mobility of Luso-Brazilian elites such as Couto Ferraz, the director of the botanical garden in Rio de Janeiro, Brazil, while accompanying the emperor to places such as Kew Gardens (Hickman Bediaga 2011, 100). Local “assistants” and naturalists from the tropics are also agents of knowledge flows that accompanied long distance botanical missions of Portuguese as well as Spanish-American botanical expeditions (Rocha Barbalho da Cruz , Wilton Appel). However, mobility was not limited to colonial elites. Indigenous groups engaged in mobility as part of exchanges, and the work of de la Puente Luna on legal intermediaries from Peru that engaged in mobility to the Spanish empire suggests that these sorts of relations shaped issues of land and associated agricultures (Foreman 1943, de la Puente Luna 2010, Weaver 2014).

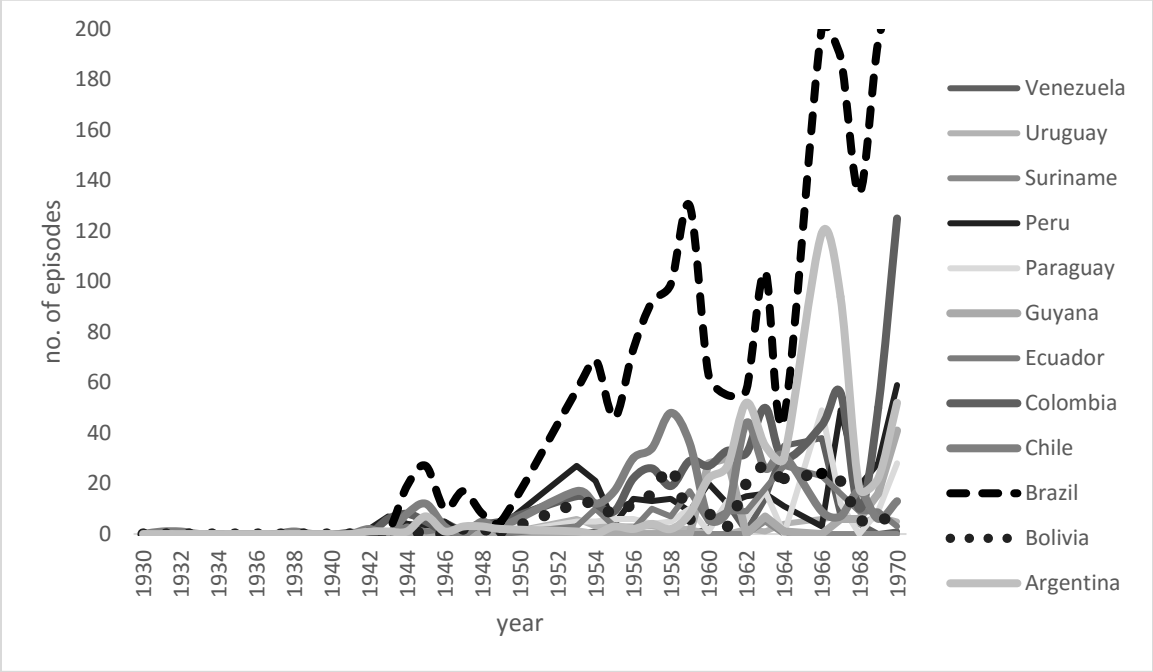
Elites from the Portuguese and Spanish colonies also engaged in education and training in natural sciences in distant locations (Rocha Barbalho da Cruz). A key inter-regional example were Luso-Brazilian elites, including from Minas Gerais, that traveled during the colonial period to the University of Coimbra in Portugal to study natural history, with an estimated 2,500 students receiving degrees from the University of Coimbra between 1577 and 1822 in an era when universities did not exist in Brazil (Ferreira 1966, Dias da Silva Campos and Moraes dos Santos 2012, Casoni Moscato). Two students of natural sciences from Minas Gerais, Camara and Couto, who received scholarships for a ten-year journey through Europe and then returned to Brazil to specialize in mining were also concerned with agriculture and connected to government projects at home and diplomatic contacts abroad that contributed to flows of knowledge back to Minas. These mobile naturalists, for example, sought ideas for institutional reform in Brazil and believed that improvements in agriculture could bring economic development (Figuerôa and da Silva 2000, Varela). A select number of individuals from Bolivia trained outside of the country during the early national period but the limited view that such elites held of agriculture as a profession are likely to have made this a negligible field of learning while abroad.

The missions of São José from Minas and Cárdenas from Cochabamba express the initiatives of actors in the newly-independent republics of South America to establish higher education in agricultural sciences in the context of the waning of the liberal export era from 1900 to 1940 and the global depression of the 1930s.[7] Beginning around the year 1900, there were early cases of mobility of local scientists to distant locations as part of scientific training as well as institutional design of educational systems but there is little reliable comparative data on these isolated processes from Latin America until 1930.[8] Data collected by the Institute of International Education (IIE) provides rough estimates of the number of individuals from South America that were enrolled in education in United States universities but this data does not disaggregate agricultural sciences as a field of study. Beginning in the 1930s, the internal reports of inter-American funding and facilitating organizations provide the earliest reliable evidence of these cases of mobility. Figure 2-1 presents new evidence from United States government and philanthropic reports on the magnitude and geographical origin of mobile scientists from tropical agricultures in South America.

[7] Prior to 1940, we document the cases. From Bolivia, Martín Cárdenas (1935). From Brazil, Antônio Secundino de São José (1936), Braga (1936), Drummond (1936). From Argentina, Horowitz (Vessuri 2014). Manuel Elgueta Guerin, was a Guggenheim Fellow to California and Cornell in 1931 (Elgueta Guerin 1986). In 1932 C. A. Krug was sent by the Instituto Agronômico of São Paulo, Brazil to Cornell University to specialize in genetics, cytogenetics, and the improvement of plants and returned to found a research group to work in the improvement of coffee and corn.

[8] Institute of International Education (IIE) data beginning in 1919 provides estimates of the presence of individuals from Latin America in universities in the United States but does not disaggregate by field. There is isolated evidence, for example, of initiatives such as that of the government of Bolivia sent a handful of students to study agricultural and veterinary sciences outside of the country between the year 1906 and 1915, which the following section briefly describes. A gubernatorial executive order from 1911 suggests that the Government of Minas may have subsidized the training of apprentices in the agricultural sector in the United States and Europe (Governor of Minas Gerais 1911).

Figure 2-1 Number of Mobility Episodes of Agricultural Scientists from South America Facilitated by United States-based Organizations, by Country of Origin,1930-1970



Sources: (Guggenheim Foundation , IIE, Rockefeller Foundation , USAID (United States Agency for International Development) , Maddox and Tolley 1957).

Notes: Mobility episode counted in calendar year of departure date based on calendar year for the Rockefeller Foundation and Fiscal Year from July 1 to June 30 for USAID. Years 1950-1952 and 1965 are not displayed due to incomplete data and episodes via USAID in 1955 only cover the period from July 1, 1954 to Mar 31, 1955.

The geographical origin of mobile scientists at the unit of the country serves as a proxy for the locational diversity associated with mobility from contexts that are more varied than the sites of the Mexican Agricultural Program of the Rockefeller Foundation. Organizations through which scientists circulated included higher schools of agriculture, private public scientific institutes, experiment stations and agricultural extension organizations but also private agricultural firms in various sectors.[9] This locational diversity also serve to demonstrate the range of environments as well as political ecological contexts that shaped agricultural systems within the general framework

[9] For example, McCook suggests that Chardón, from Puerto Rico, conducted graduate study through family wealth (McCook 2001). IIE data on the total number of individuals from Latin America that studied in universities of the United States in any discipline combined with the limited general preference of elites for agriculture as a field of study suggests that cases of study through family wealth were modest

of dual systems of large and smallholder agricultures. These systems of mobility reflected not only the “home” locations in the tropics but also the ways that mobility served to connect different subnational sources of knowledge – and associated institutional and political ecological arrangement at multiple different distant locations. These were a select cadre of scientific elites such as professors and students of agricultural sciences but even within these experiences there is evidence that suggests that individual-level variation in social positions, backgrounds and knowledge specializations across fields such as agronomy, genetics, economic botany, medical sciences, forestry and social sciences of agriculture influenced these episodes of mobility in different ways.

Mobility and the Acquisition, Absorption and Application of Knowledge in Latin America

How did the mobility of scientists from Latin America since 1900 influence the acquisition absorption and application of distant knowledge within their “home regions”? Evidence of flows of knowledge and the way that this spills over between people is difficult to demonstrate but large-scale surveys of circulating individuals for internal evaluation provide a source of insight into the outcomes of individual knowledge as well as knowledge spillovers associated with US government programs from 1940 until 1960 (Loomis 1948, Gollin 1966). The attainment of degrees is an indicator of acquisition of formal scientific knowledge but the discussion of “non-technical” knowledge within these surveys also suggests that learning comprised a broader spectrum of partially-tacit scientific and institutional knowledge (USAID 1964, 129). These studies assumed that knowledge “transfers” were relatively automatic but they also hint at multiple dimensions of learning that spilled over to people in home locations (USAID 1963, 37, 1964, 103). One study that sought to evaluate the individual-level factors of knowledge transmission pointed to the unexpected finding that “underlying institutional arrangements emerge as significant influences upon the outcomes of… [participant training] on technological change.” The next section parses

these factors by examining missions of mobility from the two regions of Minas Gerais, Brazil and Cochabamba, Bolivia.

MULTI-DIMENSIONAL MISSIONS AND PATHS OF MOBILE LEARNING

In 1935, the botanist Martín Cárdenas left his public sector research on the quinine-containing bark of *cinchona* trees in the Andean slope of Bolivia just months before the agronomist Antônio Secundino de São José took leave of his university research position in the Brazilian state of Minas Gerais. These two scientists that would later go on to prestigious scientific careers were now both setting off to destinations in the United States as part of efforts that centered on the Higher School of Agriculture at Viçosa (ESAV) in Minas Gerais and the re-opening of the school of agricultural sciences at the University of Cochabamba. The basic chronology of the episode of mobility for São José consisted of one month studying rice production at the Stoneville experiment station in Mississippi and then to Ames, Iowa where he would complete a master of agricultural sciences degree with a specialization in genetics at Iowa State. For Cárdenas, this episode lasted for three months and began with meetings with specialists in tropical crops in Washington D.C. at the United States Department of Agriculture (USDA) and then to meetings and botanical study that revolved primarily around the Smithsonian Museum and the Botanical Garden of New York. These and other cases of long-distance missions by São José and Cárdenas between 1930 and 1945 serve as cases through which to explore the historically-constructed set of relations in Minas and Cochabamba that formed inter-regional geographies of learning in this early era of tropical modernization.[10] These findings demonstrate that both scientists actively learned through social

[10] In 1945, Cárdenas also spent nine months at the School of Agriculture in Cambridge, and then three months in 1945 traveling across multiple cities in the United States. This included agricultural research institute at Blandy Farm in Virginia where he studied tomatoes as well as rubber seeds. He later spent time at the Gray Herbarium at Harvard, the Field Museum in Chicago and the College of Agriculture at Cornell University in Ithaca, New York concerning research on potatoes. Cárdenas visited the Department of

networks and practical experiences beyond formal scientific principles but that the missions suggest that the way that these pioneers constructed learning through historically-constructed sets of relations shaped more specialized inter-regional and inter-organizational geographies of learning for São José but more diffuse efforts of Cárdenas.

Searching for Modernization

In the early 1900s, politicians, scientists and other actors in Minas and Cochabamba envisioned a new local corps of elite plant scientists as part of regional schemes that looked globally to modernize moribund feudal and slave-based agrarian regimes that encumbered agricultural diversification and productivity. In Minas, the state government began in 1920 to establish a Higher School of Agriculture (ESAV) in Viçosa, a community in the so-called "forest zone" in the southeastern region of the state that would open in 1926.[11] In Cochabamba, the federal government opened Bolivia's first higher Institute of Agricultural and Veterinary Sciences in 1911, although this would close and re-open under multiple bureaucratic guises before becoming a higher school of agriculture in 1938 in the University of Cochabamba. These scientific corps formed part of a search for a "modern" alternative to land distribution as the route to agricultural productivity in the context of deep-seated but crumbling colonial tenure and labor institutions based on indigenous communities in Cochabamba and slaves in Minas (De Janvry 1981, Blasenheim 1982, Jackson 1994, Bergad 1999, Gotkowitz 2007).[12] In the early 1900s, this search

Agronomy at the University of Minnesota as well as the University of Virginia. At the Bronx Botanical Garden in New York he conducted meetings on cinchona crops.

[11] There is a literature by Brazilian specialists in Portuguese on the founding of ESAV, see e.g. (da Silva).

[12] Events in the first decade of the 1900s such as the creation of a federal ministry of agriculture in Bolivia in 1904 mark the beginning of this phase, although there was a longer lineage of debates, for example, in 1861 the government of Bolivia passed a project to establish such a school in Cochabamba by bringing in foreign agronomists as professors (Government of Bolivia , Rodríguez 2005). Projects of economic recovery between state and private sector elites in Minas from 1903 mark the beginning of these discussions, but there was a longer history of agricultural education and training in other locations in Brazil prior to World

extended to global scales as regional economies in Minas and Cochabamba sought to offset waning global exports: coffee from Minas and São Paulo, Brazil, tin from the Andean plateau of Bolivia, and rubber from the western Amazon periphery that straddled the two countries (Fifer 1970, Weinstein 1983, Pacheco B 1992, Contreras 2000, Paiva Abreu and Bevilacqua 2000). The formation of these scientific corps in the aftermath of commodities booms also grappled with climatic variability, concerns over deforestation, sanitary issues in agricultural and animal trade and other regional concerns that was part of economic shifts at wider scales (Rolfs 1936, Jackson 1989, 279-281).

Global dimensions of these regional projects to establish higher schools of agriculture comprised two relational mechanisms: the secondary mechanism formed by the outward human mobility of São José and Cárdenas, and the primary mechanism based on the inward mobility of foreign advisors contracted by politicians in Minas and Cochabamba. In 1907, during the Presidency of Ismael Montes, the first Minister of Agriculture of Bolivia, Manuel Ballivian, initially looked to the Gembloux School in Belgium for models of agricultural education for Cochabamba although the Minister ultimately contracted Giuseppe (José) Torreggiani, an Italian-born veterinarian in the state agricultural research system in Buenos Aires, Argentina (MCA 1905, MCA 1907, 105, MCA 1908).[13] In 1920, the Governor of Minas Gerais, Artur Bernardes, sought the counsel of the United States Department of Agriculture via Brazilian diplomats in order to eventually – after two initial offers –contract Peter Rolfs, an Iowa-educated specialist in tropical agriculture from the agricultural experiment station at the University of Florida.[14] The plans of local politicians in Minas and Cochabamba for “models of scientific agriculture” were translated through

War II (Campos de Araújo 1979, Capdeville 1991, Pirró e Longo and Derenusson 2009, Valentim da Silva n. d.).

[13] On Torreggiani as part of the migration of agronomists from Italy to new public research institutes in Argentina see the brief discussion in (Tranchini 2013, 381). On the wider importance of Belgian agronomists for governments in South America around 1900 as well as the particular aspects of Bolivian preferences for Gembloux agronomists see (Government of Bolivia 1917, Stols 1976).

[14] There is a small specialist literature in Portuguese on ESAV based on local university and regional sources (Marcelo Ribeiro and Porfírio , Valentim da Silva), in addition to personal papers and organizational reports of Rolfs held at the University of Florida.

particular sets of local contacts and transnational relations challenge explanations of the wholesale transfer of foreign models such as United States land grant universities or a Belgian model of agronomical education.[15] We can examine this historical and relational construction of global dimensions of tropical modernization in the rolling tropical hills of Minas and inter-Andean valleys of Cochabamba by using the missions of São José and Cárdenas as social mechanisms of learning through outward mobility.

Mobilizing Elite Plant Scientists: São José and Cárdenas

São José and Cárdenas were mobile pioneers drawn from an elite scientific corps that, in the founding vision of the first Agricultural Minster of Bolivia, should possess "complete knowledge of the methods employed in modern agriculture" and also be able to "teach crop cultivation to the vast indigenous masses that today handle these issues in the country (MCA 1909)."[16] However, a brief examination of the social position of São José, who later sought a business loan indirectly from his landowning father-in-law, as well as Cárdenas, who was the son of a father in the local class of retailers in Cochabamba and a mother of Quechua "campesino" background, also suggests that applied scientific elites were not congruent with landholding oligarchies that often regarded agricultural education as a more middling practice of technicians or of the laboring classes (Castro 1988, Gioda and Arrázola 1999).[17] The two pioneers had, though, completed the

[15] Even "model" agrarian institutions such as those of United States land grant universities and experiment stations in 1860 were translated through particular missions of individual scientists to global locations, for example see Finlay (1988).

[16] In the entire country of Bolivia in the year 1900, there were less than 250 engineers in total, of which a portion can be expected to be agronomists (Contreras 1990, 322). Later data from 1959 on the socioeconomic composition of Viçosa students by the primary profession of their parents may serve as a rough guide: 46% were large or small farmers, 17% bankers, salesman or retailers, 14% physicians, engineers, lawyers, professors, accountants or dentists, 5% civil servants, 1% industrialists, capitalists, bankers, 1% military, 16% miscellaneous professions (NAS 1960, 123).

[17] Cárdenas, for example, also often bemoaned the legal – rather than scientific - training of Bolivian leaders (Cárdenas 1972, 129). However, see also Contreras who suggests that mobile graduates in agricultural engineering were the sons of the large landowners (Contreras 1990).

highest levels of locally-available education and training: for São Jose, a bachelor degree in agronomy in the first graduating class of ESAV and, for Cárdenas, high school education in Cochabamba followed by vocational training in biological and chemical sciences at the Higher Normal Institute in La Paz. In their early professional careers, São José had worked for a regional agricultural organization in the state of Espírito Santo prior to his position at ESAV, and Cárdenas taught natural sciences at secondary schools and post-secondary training institutes in Bolivia, conducted a botanical apprenticeship to scientists from the United States as part of the Mulford bio-prospecting exploration to the Bolivian Amazon, and then advised Bolivia's Military Sanitation Laboratory on quinine production related to Bolivia's engagement in the Chaco War in the early 1930s (Candia 1999).[18]

Missions within Regional Histories of Mobility

The trips of São José and Cárdenas in the mid-1930s were pioneering but also embedded in regional histories of scientific mobility since the early 1900s. São José himself attributed part of his own mobility to the third rector of ESAV, John Griffing, but additional evidence also contextualizes this in a longer historical and social lineage to early Rockefeller projects in China as well as to Rolfs, the foreign advisor and first rector of ESAV that facilitated mobility since the 1920s (Castro 1988, 48, note 1 on 152).[19] Griffing, who was a specialist in cotton cultivation as well as human demography, came to Minas with a longer experience in the mobility of "local"

[18] As a botany student, Cárdenas served as an assistant to the botanist on the Mulford Biological Exploration to the Amazon in 1921 and 1922, an inter-disciplinary bioprospecting mission by a group of scientists led by Henry Hurd Rusby to the Bolivian tropics that was funded by the H.K. Mulford pharmaceutical company, of which Rusby was a consultant and intermediary of botanical supply in addition to a Professor at Columbia University, associated with the New Yok Botanical Garden. The Mulford mission collected widely but was particularly interested in questions of banisteriopsis caapi, the bark that is a constituent element of the ceremonial hallucinogenic and the expedition was established from the outset to attract good press for the company.

[19] Rolfs alludes to the fact that students from ESAV had previously gone on to study at the University of Florida prior to the trip of São José (Rolfs 1937a).

scientists from participation in the late 1910s in the earliest Rockefeller project in “scientific” agriculture in Nanking, China that also comprised pioneering trips of mobility by agronomists from Nanking to graduate study in the United States, as discussed by Stross as well as Hill (Stross 1986, Hill 2010).[20] Comments by Griffing in the China project that expressed his regard for “skillful selection and adaptation of those modern tools, methods, and ideas from foreign countries” rather than a wholesale embrace of that which was "foreign and expensive or impractical” also suggests that he had been grappling with the selection of foreign knowledge by “local” scientists when he arrived in Minas (Stross 1986). Evidence from correspondence that Rolfs also actively corresponded with and lobbied government, scientific and philanthropic contacts such as the Pan-American Union with regard to bi-directional exchanges between ESAV and the United States since the 1920s and 1930s not only situate Rolfs as a key figure in the missions of mobility but also situates São José in a wider web of relations.

In Cochabamba, the mission of Cárdenas in the 1930s should be seen in the lineage of a previous ambitious, but ultimately unsuccessful, effort of the government of Bolivia between 1906 and 1915 to send between ten and forty individuals for education and training in agricultural and veterinary sciences in Argentina, Chile and the United States. This unfolded in parallel to the regional project led by Torregiani to establish higher education in agriculture that was hampered by budget shortages, the beginning of World War II, and the suspicion of large landholders to the educational project in agriculture (MCA 1905, 8, Government of Bolivia 1917, Suárez Arnez 1963, Contreras 1990, Calderón 2008, Iño Daza 2012).[21] Cárdenas himself bemoaned the

[20] The question of racialized theories of genetic selection – of both crops and humans – in the formation of regional histories of agronomic mobility is beyond the scope of the current study. Griffing, whose published research examined differential birth rates, espoused the view that frontier regions of Minas Gerais were social “sifting grounds” in which ‘no democratization of education for the masses swamp[ed]” higher education although he also suggested that cultural ‘beliefs, ideals, attitudes, and values’ played a part in “lifting [man] out of the realm of natural law governing the reproduction of plants and animals (Griffing 1940, 1941, 150).” Griffing’s work is also cited in later editions of Casa-Grande e Senzala, Gilberto Freyre’s treatise on Brazilian race and nation (Freyre 1961). For a comparative view from Latin America of the influence of eugenicist theories in early agronomic science, see (Stepan 1991).

[21] This estimate is derived from estimates by Contreras and Iño Daza. The larger fellowship program represented ten per cent of the entire student population in Bolivia and the send-off of students was

'disillusionment' and 'pain of remembering' the lost opportunity to integrate foreign scientists into the Cochabamba institute. Although he does not discuss the parallel effort in mobility, he was certainly conscious of this ambitious undertaking and was part of these prior events (Cárdenas 1943). His lack of discussion of the parallel of these two mechanisms of knowledge between mobile local agronomists and inward foreign advisors may also suggest that the lack of coordination between the two efforts focused on the new institute.

Mobile Scientists and Political Plans for Tropical Modernization

São José and Cárdenas were active agents of their respective projects of mobility in the context of the mid-1930s era of depression and the Chaco war in Bolivia. Cárdenas engaged in episodes of mobility at extra-regional scales to explore new tropical regions in Bolivia. His ambitions stretched to global scales, as suggested by his extensive correspondence with specialists around the world as well as his close and critical study of the nature of foreign travel to Bolivia. Cárdenas had also already sought out knowledge beyond national borders when he traveled to Santiago, Chile for three months in 1931 in search of "ocean air and new relations" at the National History Museum, where he actively established contacts with scientists from Chile and beyond (Cárdenas 1972, 38).[22] Evidence in the correspondence of Rolfs also suggests that São José was an active participant in shaping his own mobility. Cárdenas and São José were

attended by the President and the Minister of Education with great fanfare (Contreras 1990, 176-177, Iño Daza 2009, 126).

[22] Cárdenas maintained and corresponded with extensive relations with extra-local source of knowledge, including Posnansky, who was his friend at director of the Museum of Tihuanacu, and had arrived in 1920 for collection, and who later introduced him to Erik Asplund, the Swedish botanist who left his equipment to Cárdenas in early 1921. Posnansky was an Austrian immigrant to Brazil who worked for Bolivia during the war of Acre as a riverboat captain. He later returned to Bolivia from Europe after having been captured by Brazilian forces. Posnansky was interested in the archaeology of Tihuanacu and later became the director of the national museum. He published with Cutler (Bowman).

agents of their own mobility but they simultaneously moved in relation to political visions for tropical modernization.

In Cochabamba at the time, the President of Brazil. José Luis Tejada Sorzano was a landed oligarch and former vice president of the ruling party whom the Bolivian military installed in the Presidency at the end of the disastrous Chaco War. President Tejada Sorzano sent Cárdenas to the United States with the goal to resurrect the shuttered higher school of agriculture in Cochabamba as part of a broader push for agricultural modernization in the Bolivian tropics (Cárdenas 1972).[23] Cárdenas regarded the President as "scrupulous and possess[ing] a European mentality" and approved of his concern for "the technification of our agriculture" (Cárdenas 1972, 69). In their meeting just days before the trip, the President told Cárdenas that he sought to 'technify and rationalize agriculture' to produce quinine and fruit in the tropical Yungas region of the eastern slope of the Andes that had traditionally supplied tropical produce to the highlands (Bolivia President 1935, Cárdenas 1972, 1968). His vision, perhaps shaped by his experience in commercial relations in the United States for the Bolivian government, was of southern California orange fields as a model for a modern Yungas region that was free of agricultural plagues and producing high quality products for global markets .

Oranges also shaped part of the vision for Minas, as expressed by the figure of Rolfs who was a specialist in citrus trees.[24] The role of Griffing during the mid-1930s when the government of Minas was seeking to expand cotton production to offset plummeting coffee prices, also suggests that cotton production was a possible focus of São José that later shifted during the stay in Iowa. Rolfs wrote the letter of recommendation to Iowa State for São José and then penned a second letter to R. Howard Porter, the Dean of the School, in which he plays off regional competition and

[23] This included an effort to establish a new agricultural experiment station in the region where the family of Tejada Sorzano possessed a hacienda, as well as an unusual public private agreement to establish a temporary school of agriculture with the powerful Suarez firm in the Amazon state of Beni (Bolivia President 1935, 1936).

[24] On the social construction of the Southern California orange industry during this era see Cazaux Sackman (2005)

emphasizes the practical nature of Midwestern training in order to make his case that Iowa State was "not receiving a just percentage of students from Brazil" in comparison to the north-to-south mobility of professors from Iowa to Brazil:

> Geographical and commercially Iowa's location is against her. New York is the usual port of entry; all Brazilians contact with the Consul General. He has heard of Iowa but known nothing of I.S.C. Rarely does a student get as far west as Wisconsin and rarer yet to Texas. The eastern institutions educate the Bra[z]ilians and they get a provincial ideal of the United States. The eastern institutions educate for the laboratory, away from the industry, agriculture…Brazilians, especially Mineirans, like the Western ideals (Rolfs 1937b).

These political and academic projects shaped the initial outlines of missions but these two scientists both constructed broader processes of learning in distant locations in ways that were not defined by political visions of modernization.

Multiple Dimensions of Mobile Learning

The missions of São José and Cárdenas on the ground in locations in the United States demonstrate a wider breadth of learning processes than explained by the existing diffusionist literature on the acquisition of Western scientific principles or the manpower planning literature on the acquisition of graduate degrees.[25] São José wrote from Ames, Iowa to Rolfs in Minas that "since I came here I have tried to keep my eyes and my ears widely open in order to get all experience that I can, and, I think, I have got a good deal of it (São José 1938b)." This search for a breadth of knowledge is also evident in comments that Cárdenas made in 1945 at the conclusion to his second mobility episode to the United States when boasted that he had gained an "enormous experience in a short time" by designing a sever schedule of visits to "ten cities,

[25] Cárdenas brought back an array of codified literature from the United States Department of Agriculture. The global missions also express the acquisition of codified global knowledge as part of the modernization of local agriculture. For example, in Bolivia Ballivián sought to build up global knowledge through the acquisition of libraries and collections of books from abroad.

visiting, four of the largest herbariums and more than five centers of higher education in agricultural sciences (Cárdenas 1972, 127).” The social relations that these scientists learned through – what we can approach through the concept of know-who – helps to explain the social nature that provided access to not only the formal scientific principles of know-what and know-why, but also to institutional knowledge on the organization of institutional contexts for agricultural innovation as well as the application of agricultural knowledge.

The existing literature on the trip of São José has privileged the role of maize seeds that São José brought back from the United States in explanations of knowledge transfer but evidence of the acquisition of material technologies was more widespread rather than an anomalous case and thus only a partial factor in learning through mobility. The comments of São José quoted in Castro suggest that material acquisition was an active strategy of São José, as he stated that “I brought a kilo of that tuxpan variety that I grabbed in Texas,” referring to varieties of corn that Paul Mangelsdorf, who years later would become part of the Rockefeller team in Mexico, was developing at the experiment station at Texas A&M university in College Station. Cárdenas was also a tireless collector and though he does not mention actively material acquisitions such as seeds and plants during his trip to the United States in 1936 but he does mention it on other occasion that he comments on a trip to Ecuador that suggests that this was a regular part of his repertoire when he emphasized his material acquisitions, arguing that he boarded the plane with “various leaves and cuttings of cactus instead of the leather wallets, palm straw hats and other typical Ecuadorean gifts like tourists do (Cárdenas 1972, 176). The material acquisitions by these scientists is also corroborated by scattered reference to active material acquisitions by tropical scientists as a regular part of their learning repertoires.[26] However, as Castro suggest but does not

[26] For example, Americo Groszmann from ESAV was also a source for transnational transfer of germplasm, and Gandarillas was offered germplasm to develop at Cochabamba (Griffing and Lindstrom 1954, Gandarillas 2001). Analysts of other locations also note that Horowitz brought back various sorts of maize germplasm as well stocks of fruit flies from Cornell University to Argentina (Mazoti and Hunziker 1976).

fully develop, the travels of the scientists as part of learning was about more than as a simple carrier of seeds.

Part of the explanation is that mobile scientists actively acquired practical knowledge of agricultural innovation – what we can approach as know-how – that was necessary to unlock certain technological potential of material acquisitions. This included practical forms of know-how, as São José stated in a letter to Rolfs that he was "learning, by observation and studies (São José 1938a)." This appear to have been as important as the actual seeds that came home and the learning of these scientists should be approached as socio-technological knowledge. Know-how included institutional knowledge and environmental knowledge. For São José, the relationship with Henry Wallace, as well as a broader form of connections in the particular innovative milieu of Iowa, seems to have shaped more of the success of São José in terms of his thinking on the application of innovation through firms. For Cárdenas, know-how included partially tacit forms of institutional knowledge about how to arrange not only educational systems but also the application of knowledge in innovation. The observations of Cárdenas on the organization of agricultural education and innovation as well as the institutions that shaped this come through in his notes from his travels. In 1935, he traveled with an eye to the founding the University of Cochabamba department of agricultural sciences. During subsequent trips to the United States and to England, where he visited multiple different types of organizations, he took notes on the organization of scientific education and as well as experiment stations associated with universities (Cárdenas 1972, 111). Cárdenas was learning from and seeking to translate into the context of Bolivia was that of the relationship between mobility and the organization of education in Bolivia.

Forging Inter-Regional Geographies

We can begin to examine the difference in the relations through which São José and Cárdenas engaged in learning in order to explain the construction of different inter-regional

geographies of learning that are proxies for sets of inter-regional relationships between scientists and organizations and place-based production of agricultural knowledge. While both scientists learned from a breadth of knowledge, evidence suggests that through which São José learned shaped particular geographies of learning that help him to specialize put him in a place of innovation in Iowa that would be central to broader outcomes of learning in Minas. Cárdenas learned broadly primarily by tapping relations from botanical explorers to Bolivia but these relatively diffuse relations that were unarticulated with innovation in Cochabamba limited the ability to translate learning more broadly once in Cochabamba. Connections with Iowa weighed heavily.

São José traveled with two other professors from ESAV as well as with the son of John Griffing, who was also attending school at Iowa State. Communications of São José suggest a level of arms-length coordination with Rolfs. The story of São José became associated with hybrid corn but it is not clear that he set out on a mission of hybrid corn. He ended up sitting down with Wallace over dinner. The relationship that São José developed with Henry Wallace, who was one of the most important articulators of the role of agricultural technology as part of inter-American relations – the Green Revolution – were due to serendipitous relations. This represented new knowledge on the application of scientific technology in the market, and complemented new sources of material knowledge. São José learned widely but he did so within a particular context in Ames, Iowa.

Cárdenas's mobility drew on his own relations with global researchers that were temporarily in Bolivia as well as through particular geographies of botanical gardens and museums. Central among these were contacts that Cárdenas had established through the Mulford Botanical Exploration, including with Henry Hurd Rusby who was associated with the New York Botanical Garden as well as William Mann, the entomologist from the Mulford Expedition that was now director of the Washington D.C. zoo. In the United States he traveled through botanical gardens, including meeting with Albert Speak Hitchcock, the director of the Herbarium of grasses of the USDA that Hitchcock and others had collected on trips, including to the Bolivian Yungas, a

month at the Smithsonian Institute researching quinine and others. At the Botanical Garden of New York, he met with Henry Gleason on tropical flowering plants of melastomoceae, Dr. A. S. Smith on ericaceae, as well as R. S. Williams. He followed the recommendations of botanists with research experience in the tropics of Latin America, including William Maxon with respect to the study of ferns, Ellsworth Killip on passifloraceae, the family that comprised passionfruit and other plants, and Vernon Morton, on the family that included the potato and other vegetables (Cárdenas 1972, 70). However, there is no indication in the published historical record that Cárdenas was learning in coordination with actors at home in Cochabamba.

This section did not seek to make the individual comparison at the level of the individual scientist but rather to begin to work outwards into the different sets of social relations that São José and Cárdenas coordinated with actors between the cases of Minas and Cochabamba. Part of the explanation of this can be found in differences in their fields of prior knowledge, with botanists bound to particular geographies of botanical gardens and herbariums abroad, in ways that are different from emerging genetic agricultural scientists, as McCook points out (McCook 1999). However, the pioneering missions of the two scientists is also shaped through particular historical sets of relations that in the case of Cochabamba, were part of relatively unarticulated bio-prospecting networks that were part of the extraction – as opposed to integration – between foreign and local sources of knowledge. The findings suggest that the mobility of São José coordinated with foreign advisors in Minas but Cárdenas partially disconnected from foreign actors in the case of Cochabamba. These sets of relations help to approach the pioneering cases of mobility of São José, Cárdenas as an entry to the regional governance of systems of mobility from 1945 to 1960 in the following section.

CIRCULATORY SYSTEMS AND CULTIVATED CAPABILITIES OF REGIONAL LEARNING

The extra-local knowledge that São José and Cárdenas acquired in the United States and other locations fed into their home regions during a complex juncture when the mobility of plant scientists intertwined with new scales and political ecologies of agricultural technology within cold war technical assistance, revolutionary reforms in Cochabamba in 1952 and shifting politics of economic development in Minas. A growing cadre of mobile plant scientists associated with new clusters of interventions in education, research and rural extension of agricultural technology around ESAV and a reopened higher school of agriculture in the University of Cochabamba influenced regional outcomes in ways that the existing literature does not address.[27] This section moves from the previous discussion of mobile learning at the unit of the individual mission in the late 1930s and early 1940s to examine inter-relational and inter-organizational relations that formed the governance of systems of circulation in Minas and Cochabamba mediated regional learning from this cadre of mobile plant scientists between the mid-1940s and the mid-1960s. This section suggests that cross-pollinating forms of coordination in Minas shaped wider regional spillovers of extra-local knowledge from mobile learning in contrast to Cochabamba where fragmented enclave forms of coordination limited learning of extra-local knowledge to the Inter-American Agricultural Service (SAI) that was sustained by technical assistance experiments of the United States government. This section uses a critical juncture in the late 1950s to suggest regional capabilities to learn from extra-local knowledge as a concept that can help to explain the ways that historical processes of regional learning through these two forms of governance shaped variation in agricultural innovation in ways that suggest the need to revise existing narratives of the origin of national organizations of agricultural research in Brazil (EMBRAPA) and Bolivia (IBTA) from the mid-1960s.

[27] This paper adopts the acronym ESAC (Higher School of Agriculture of Cochabamba to refer to the school of agronomy at the University of Cochabamba which underwent name changes over the years.

Regional Clustering and Circulatory Systems

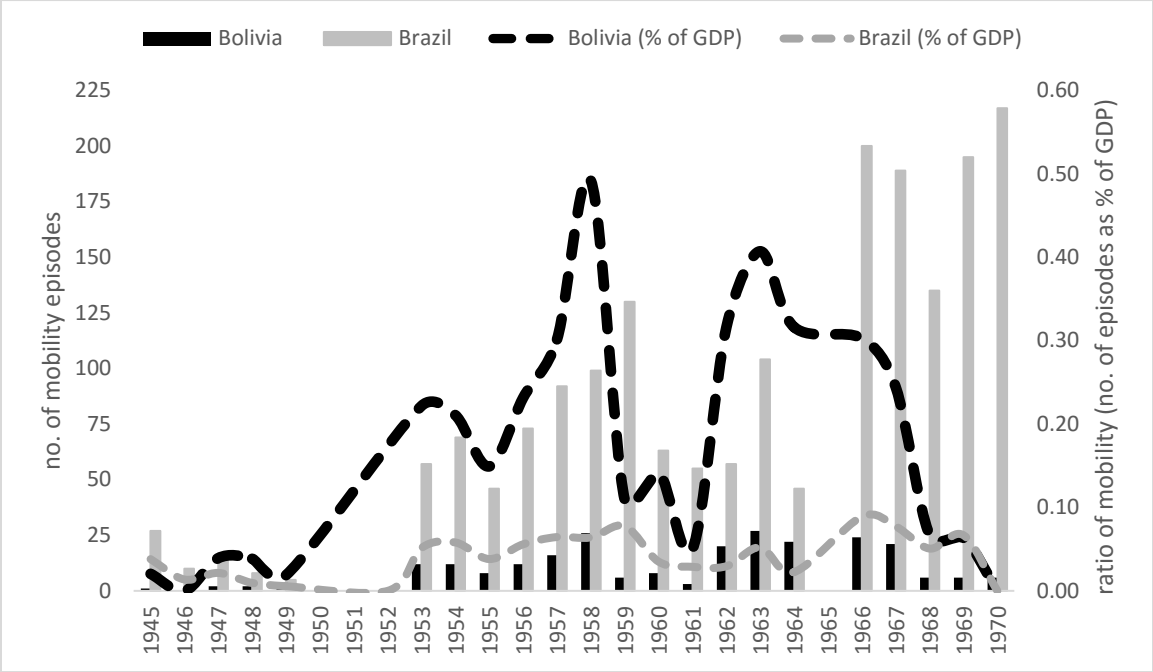
São José re-integrated into the research program at ESAV after returning from the United States but Cárdenas would only later oversee the founding of higher school of agriculture in 1938 when he became the rector of the University of Cochabamba through an unexpected pathway that was disconnected from the initial plan of the now-deposed ex-President Tejada Sorzano for agricultural modernization. Differences between the two cases in the capacity of publicly-funded universities to absorb knowledge by retaining circulating plant scientists may help to explain part of the differences in regional learning but it is not sufficient to explain the forms of coordination between universities as locational hubs for new interventions in agricultural education, research and extension shaped learning in relation to other organizations such as local and foreign governments, philanthropies and private firms in the region. Part of the basis in the two cases is that different sets of organizations grew up around higher schools of agriculture in Minas and Cochabamba, with a greater variety of organizations coordinating with ESAV on the mobility of plant scientists in contrast to Cochabamba where extra-local learning was primarily associated with the Inter-American Agricultural Service (SAI). In Minas, new interventions in the late 1940s and early 1950s included: i) extra-local training of ESAV professors through an agreement between ESAV, US government organizations and Purdue University in 1949, ii) the founding of the Association of Credit and Rural Assistance (ACAR), a rural development organization focused on agricultural extension that was a project of the American International Association (AIA) of the Rockefeller Foundation and the government of Minas in 1949, iii) support to mobility from a binational commission to govern technical assistance efforts between the United States and Brazil, in addition to other initiatives. In Cochabamba, mobility associated with agricultural technology centered almost exclusively on the Inter-American Agricultural Service (SAI), an organization of agricultural research, extension and rural development that was part of an organizational model that the Office of Inter-American Affairs (CIAA) of the United States

Government which possessed a national remit but centered on the site of the La Tamborada research station on the edge of the city of Cochabamba.[28]

A modest but growing number of plant scientists associated with these organizations formed cadres from Minas and Cochabamba that engaged in long-distance missions in agricultural, veterinary and forestry sectors to locations in the United States as well as Latin America. Figure 2-2 presents the number and GDP-adjusted rates of mobility in agricultural and related sectors from Bolivia and Brazil between 1945 and 1970 based on data from government and philanthropic organizations from the United States that provided the leading (but not sole) source of funding and bureaucratic support for scientific mobility in agriculture from Latin America over the course of this era.

[28] In addition to La Tamborada, the SAI was organized spatially through a subsequent acquisition of the Belen hacienda in the Achacachi municipality in the arid highland plateau of La Paz and an additional plot of land located forty miles to the north of the city of Santa Cruz in the eastern subtropical region of the country.

Figure 2-2 Mobility Episodes in Agricultural Sectors from Bolivia and Brazil, 1945-1970



Sources: (Guggenheim Foundation , IIE , Rockefeller Foundation , USAID , Maddox and Tolley 1957)

Notes: Mobility episodes are counted by departure date by calendar year or first half of fiscal year. Years 1950-1952 and 1965 are not displayed due to incomplete data and USAID data in 1955 only covers the months from July 1, 1954 to Mar 31, 1955.

The increasing quantity of mobility episodes was necessary to open potential channels to extra-local learning but the higher rate of mobility from Bolivia in comparison to Brazil over much of this date range suggests that a simple aggregation of mobility episodes is not sufficient to explain more complex variation in regional outcomes of extra-local learning between Minas and Cochabamba. Viewing the two series together does, however, point to an inflection in processes of mobility in the late 1950s that we can use to examine divergence in paths of extra-local learning from Cochabamba and Minas during a key juncture of change that followed the Bolivian revolution and preceded the founding processes of national organizations of agricultural research after the

mid-1960s. Examining the underlying processes of mobility suggested by this data at the national unit becomes more visible by analyzing systems of circulation at the regional level.[29]

The evidence of learning in organizations in both regions suggests that the contribution of mobility to regional learning from extra-local knowledge was possible in both cases and was not pre-determined in the Cochabamba case. The initiative between Purdue and ESAV, which was initially part of an effort focused on ACAR but later developed into a pillar of USAID efforts on agricultural education in Brazil emphasized the training of local scientists from Minas (Peterson, Schaeffer, and Capener 1969, 8). In Cochabamba, the SAI emphasized the training of local scientists, with Cárdenas stating that "almost all of the national technicians that should have gone were sent to the United States to conduct advanced training at the postgraduate level" and Humberto Gandarillas, another mobile scientist, stated that the SAI gave special attention to the training of Bolivian personnel (Cárdenas 1972, 220, Gandarillas 2001, 48). By 1958, the extension service of the SAI consisted of 103 agents in sixty provinces and seven of Bolivia's nine subnational states and an internal evaluation of the USAID agricultural programs in Bolivia by Stanley Andrews, an independent consultant that had worked both for the USDA as well as the CIAA, stated that the extension service of the SAI which centered on Cochabamba had the most qualified personnel of any organization in the entire Bolivian government (Andrews, Myrick, and Samson 1962, Heilman 1982, 67) In the mid-1940s, Cárdenas did find a more interested environment in Cochabamba as he returned home from England and the United States in ways that The ACAR program emphasized the progressive training of extension agents and personnel at the local supervisorial level at global scales via ICA funds with an effort to prevent discontinuities (ACAR 1959, 19-21). Specialists have used the ACAR case as an example of positive outcomes in agricultural innovation but the evidence from the counterpart agricultural

[29] The United States government provided the primary source of support of mobility of scientists from both Minas and Cochabamba but there are no consistent data sources that permit the disaggregation of mobility beyond the unit of the country.

extension organization of the SAI suggests that lackluster outcomes of agricultural innovation in the Cochabamba case by 1960s was conditional on other factors and not a foregone conclusion.

Regional Learning from Extra-Local Knowledge through Individual Scientists

Learning was an inter-relational process because both São José as well as Cárdenas moved in and out of the university in addition to interacting with growing regional cadres of mobile scientists that formed in their respective regions. Data at the subnational level from the Rockefeller Foundation demonstrates the mobility of multiple scientists from ESAV in comparison to ESAC, from which only three individuals engaged in mobility via Rockefeller Foundation fellowships.[30] Aggregate lists of agricultural scientists with advanced degrees from Latin America in the mid-1960s points to certain inter-regional patterning of geographies of long-distance missions from systems of circulation from Minas and Cochabamba. For example, scientists from Minas to Purdue University and Florida and scientists from Cochabamba to Minnesota and international training sites such as Turrialba, Costa Rica suggest that relations between mobile scientists as

[30] The best available estimate in technical reports is that 249 individuals from Bolivia received grants for training in the agricultural sector from the associated technical cooperation organizations of the United States government between 1943 and 1963 (USAID 1964). This is consistent with Gandarillas, who states that ninety-three Bolivian staff of the SAI received training over the course of a decade in the mid-1940s when La Tamborada and the Cochabamba region provided a primary source of agricultural scientists (Gandarillas 2001). Data from fiscal year 1957 shows that of the 31 Bolivians were trained in the agricultural sector, approximately half trained in locations in the United States, one quarter in Puerto Rico and one quarter in other third countries that are likely to have been concentrated in Latin America. There is also evidence that some individuals from Bolivia and other countries in Latin America studied at ESAV (Souza Oliver). IIE data on mobility from ESAV demonstrates the mobility of the following individuals: in 1940, Otto Lyra Schrader (University of Florida); 1940, Ady Raul da Silva (Wheat culture, University of Minnesota) to University of Minnesota, Federico Vanetti (Wheat culture, University of Florida), Raul Briquet Jr. (Ecology, Iowa State), Edson Potsch Magalhães (Rural Economics and Farm Management, Iowa State); in 1945, Paulo de Tarso Alvim Carneiro (Plant Physiology, Cornell), Americo Groszmann (Agriculture, Iowa State), Jurema Aroeira (Horticulture, Florida), Homero Diniz (Agriculture, Lousiana State University); in 1946, Moacyr Gomes de Freitas (Parasitology, Michigan State); in 1947, Leonidas Machado Magalhães (Veterinary Medicine, Michigan State), Alberto Monteiro Wilwerth (Veterinary Medicine, Michigan State), Franz William Wyler (Irrigation, Colorado State), Raul Briquet (Anima Breeding, Iowa State), Homero Diniz Freitas (, Edson Potsch (Agricultural Economics, Iowa State); in 1948, Joaquim Mattoso (Animal Husbandry, LSU), Francisco Megale (Veterinary Medicine, Michigan State), Jurema Aroeira (Horticulture, University of Florida), Alberto Monteiro Wilwerth (Veterinary Medicine, Michigan State), Franz William Wyler (Irrigation, Colorado State).

well as between organizations and agents in the two regions connected mobile scientists to particular places of knowledge production shaped by particular sets of innovative agents and ecologies (IICA 1965). The cases of two mobile agronomists, Humberto Gandarillas who had relations to Cárdenas in the university in Cochabamba, and Eliseu Alves who had relations of São José at the university in Minas help us to examine the inter-relational pathways of learning of individual scientists as well as the ways that their trajectories knit together a regional system over time. Humberto Gandarillas, who was from a landowning family that had subdivided land across multiple family members in Cochabamba had gone to study for his BS in agricultural engineering at the University of Chile in Santiago before returning to study with Cárdenas in the mid-1940s. Gandarillas stated that relations with travelers in Cochabamba and with Cárdenas shaped decisions regarding mobility:

> When I returned to defend my thesis in Cochabamba under professor Martin Cardenas, I met more than one classmate that had obtained a Master of Science in the United States and that was then working on in the Department of Genetics with a fellowship from the Rockefeller Foundation. This was one of the greatest incentives in my professional career to obtain a Masters degree at a North American university (Gandarillas 2001, 45).

Gandarillas briefly worked for the newly-founded Department of Genetics at the Ministry of Agriculture and later taught at ESAC in the fields of genetics and phytopathology to cover for the absence of Cárdenas during his year at Oxford in 1945 (Jackson 1994, 188). A counterpart to Gandarillas in the case of Minas was Eliseu Alves, who was born in Southern Minas Gerais, and who completed his degree in agricultural engineering at ESAV in 1954, including two years of learning under São José, who was the rector of ESAV. Alves later began to work with ACAR on rural extension programs.

These mobile scientists also shaped regional learning because they moved into and out of the university. São José served as a professor at ESAV but he would later work at General Mills in Brazil and found a hybrid corn firm after he returned to ESAV. Cárdenas would also leave the rectorship of the University, become rector again for a second time in the mid-1950s at the behest

of the post-revolutionary ruling party, but then renounce his association with the University in frustration.[31] In 1946, Gandarillas traveled to the Twin Cities in Minnesota – one of the same universities that Cárdenas visited just months prior - where he studied potatoes in the horticultural program with a specialization in plant genetics at the University of Minnesota.[32] In 1955, he returned to complete training on the organization and administration of experiment stations at the University of Minnesota 1955, Fort Collins and Hays, Kansas. Alves also conducted two trips of mobility to the United States, although to Purdue University, which maintained exchange programs with ESAV. ACAR granted him a leave of absence and he travel to West Lafayette, Indiana where he completed his Master of Science on extension services and PhD in agricultural economics at Purdue University on labor markets and agricultural development (Alves 1968, 1972). We can use these two cases to illustrate the relations at the level of the individual that began to shape between individuals but these individual relations also formed in an environment shaped by inter-organizational governance within the two regions.

Universities as Hubs of Inter-Organizational Governance of Extra-Local Learning

Universities in Minas and Cochabamba demonstrated different relations to other organizations in their region, with ESAV coordinating extra-local learning with organizations in ways that were not present at ESAC. In Minas, the first effort to establish a link between Viçosa and Purdue University was a project initially established by the USDA in 1949 and coordinated through the Technical Desk on Agriculture in the early 1950s as an intervention. This

[31] Both scientists became rectors of their respective universities for a period. However, the departure of São José from the University represented a move between organizations which served as a source of inter-organizational flows of knowledge that also knit together organizational relationships between organizations. In contrast, Cárdenas resigned the rectorship in retreat to his personal program of work.

[32] In Minnesota he encountered a diverse group of mobile scientists from India and China that were building programs of science at home and which created an environment in which “for foreigners, anything was possible (Gandarillas 2001).”

institutionalized the long-distance mobility opportunities of professors from ESAV in Purdue and other locations through the 1960s and was the first university-to-university effort in Brazil in agricultural training as well as one of the first in Latin America (Institute of Inter-American Affairs 1952). In Cochabamba, in contrast, only in the mid-1960s would the school of agronomy at the University of Cochabamba establish a similar project, in this instance with Utah State, but as part of a different context, and which did not shape a long-term set of extra-local mobility of local scientists. The La Tamborada agricultural experiment station near Cochabamba was operated by the university and the students are required in the last 2 years of their course to conduct some research and to have their classes at the experiment station. However, there is evidence that the university was isolated from relations with SAI, and when Cárdenas resigned from the university, his frustrated comments suggests that he viewed himself as the linkage between the university and foreign scientists (Rodríguez 2005, 213). This is also suggested by evaluation for USAID in 1962 that stated that agricultural education based on the university at Cochabamba was "a series of structurally unrelated agencies rather than a system" in which one scholar argues that university training in natural sciences at the University of Cochabamba represented an individual project of Cárdenas rather than an institutional effort (Andrews, Myrick, and Samson 1962, Galindo 2003, 3)."[33] We can extend these comments on the more general aspects of in the integration of the university to the more specific question of the mobility of scientists by examining the shifting sets of organizations from the United States.

[33] After the Bolivian Revolution of 1952, the governing MNR party requested that Cardenas take over the rectorship of the University, which he did, although when he imposed centralization, with resulting protest, he eventually resigned his post (Cárdenas 1972). The university was roiled by debates over the governance of the university of Cochabamba in the wake of the revolution of 1952 and then during the broader current of social protest in the late 1960s (Guerra Mercado).

Organizations Based in the United States

The uneven geography of philanthropic and government organizations from the United States that possessed different interests in the mobility of local scientists shaped regional learning, as demonstrated by the location of Rockefeller organizations on mobility in Minas but not in Cochabamba, where the Inter-American Agricultural Service (SAI) assumed greater influence on the mobility of agricultural scientists from Cochabamba. Rockefeller organization such as the AIA and the Fellowship program supported the mobility of scientists from the extension program ACAR in Minas had more experience in the education and training of scientists based primarily on their experience since World War I in training individuals in medicine and human genetics and the Cornell experience in China in the 1920s.[34] In contrast, the US government organizations, such as the Inter-America Agricultural Services, the USAID predecessor organizations and the national embassies used mobility primarily as a cultural exchange with the goal of influencing Cold War minds and only second for reasons of training for which little consideration was given.[35] In Cochabamba, mobility flowed almost exclusively through the Inter-American Agricultural Service (SAI) that was separate from the Bolivian civil service and the Bolivian Ministry of Agriculture, with the USDA holding the power to appoint by the director of the SAI and pay salaries (Bolivia President 1948, Cardozo 1971, 77, Heilman 1982).[36] As one US document stated, the organizations of the Bolivian government had little role in any aspects of the extra-local education and training of local scientists and that it was common practice that the "ministry official signed the

[34] In 1943, Harry Miller, the scientific scout for agricultural programs of the Rockefeller Foundation in Latin America, met with Cárdenas at the University, and, despite displaying interest in the Cardenas' collection of genetic maize sample, largely rebuffed the Cardenas´ request for institutional support, although it would provide a small travel grant for Cárdenas to visit agricultural research institutes in Brazil as well as other limited support that was not focused on institutional development of a scientific corps in the region (Cárdenas 1972, 107).

[35] It was likely Secundino that made the connection between AIA and the Minas state government to locate the ACAR project in Minas (Ribeiro 2000, da Silva).

[36] The Bolivian and United States Government established SAI on paper in 1943 as part of technical assistance in multiple sectors as part of a wartime program of the United States government but the work of SAI in Bolivia was ratified in 1947.

papers of the trainee but have no or little direct contact with the individual" scientist engaged in mobility (USAID 1964). Trainees were sent abroad but:

> On only a few occasions has the role of the Training Office risen above paper processing functions…The host country officials and agencies play a limited role in assuring training utilization. Trainees and projects have sometimes been abandoned with little or no effort to salvage the human and technical values they represent (USAID 1964).

These organizational differences manifested in different specialized geographies of mobility through which regions learned, with Rockefeller organizations sending scientists from Minas to United States universities and United States government programs sending more scientists from Cochabamba to Puerto Rica, Mexico and other sites, often for shorter-term training.

Governments

Differences in the role of state and federal governments in the governance of learning also shaped the two systems, with evidence suggesting that actors in Minas as well as the Brazilian federal government negotiated the way that the region learned, in contrast to Cochabamba, where the government was absent and then sought to nationalize the SAI organization. The federal government of Brazil shaped the governance of mobility from Minas by requiring a co-director governance of technical cooperation in agriculture after 1950, which was the only case in Latin America in which this was established. The government of Minas also played a more active role in agricultural development in the region, although the interventions of the government with regard to mobility are unclear. In contrast, the federal Ministry of Agriculture in Bolivia appeared to have little involvement with scientific mobility of the SAI, despite the blueprints for partnership in agreements. Cevallos Tovar, a professor from the University who also worked for the Department of Agriculture for periods, was able to obtain scholarships for students from agronomy to obtain practice-based knowledge in technical aspects of agricultural science but this appears to have been an exception

rather than an inter-organizational relationship (Cárdenas 1972). The Ministry of Agriculture itself noted later in 1959 that it had often absent in the activities of the SAI in the agricultural sector (MACA 1960). These differences in governance of systems of circulation can be seen through the example of the integration of returning scientists into these organizations, with scientists returning from mobility to Minas more likely to occupy positions of leadership in comparison to Cochabamba, where these encountered ceilings of the leadership positions in the SAI. In Bolivia, SAI hired scientists as staff of SAI but the differences in Minas, the ACAR project hired returning scientists in management positions, and there were never more than three technicians from the United States in ACAR at a time, in contrast to the growth of technicians from the United States in Bolivia. As one evaluation stated: “from the very beginning the program used and trained Brazilian technicians almost exclusively (Ribeiro and Wharton Jr. 1969).”

Private Sector

The private sector interests related to the mobility of scientists. One participant from the ACAR project argued that this was a public-private partnership that was rare in the history of the Brazilian public service (Ribeiro 2000, 14). A regional developmentalist coalition of government in Minas Gerais the comprised agricultural and industrial mining interests shaped the planning for scientific mobility as a way to incorporate the region into networks of agricultural innovation as part of the development of the University of Viçosa (Montero 2001b, a, da Silva , Diniz Barbosa 2012).[37] This is why ACAR took hold in Minas and not in Sao Paulo where it was also introduced. These would be continued by Juscelino Kubitschek and Bias Fortes. The Rockefeller proposal was not out of the blue, rather it was a fit with the existing program of the Government (da Silva). In the case of Cochabamba, efforts of extra-local training were unable to adapt extra-local training

[37] Agroceres supplied seeds to ACAR

for innovation to the shifting institutional context of agricultural production in pre- and post-revolutionary Bolivia. The new Bolivian government, led by the MNR party, did not diverge in significant ways from the Bohan plan, and agricultural research and demonstration centers that had been initiated during the forties were one of the most significant areas of support after 1952 (Heilman 1982). The basis of the SAI in the pre-revolutionary era, both in terms of the hacienda basis of experiment stations as well as in the composition of mobile agricultural scientists, influenced what appear to be mild efforts to shift to treat smallholders as clients.[38] The majority of extension agents and home agents were the sons and daughters of former hacienda owners. These staff often had a negative attitude towards teaching new indigenous farmers in the aftermath of the revolution (Heilman 1982).[39] In the context of the revolution this also reflected the fact that the processes were not linked to the latent demand for innovation within the new class of smallholder farmers in Bolivia.

Cultivating Capabilities of Extra-Local Search

We can use the juncture of the late 1950s to suggest that these different regional forms of learning from extra-local governance were associated with different historical processes through which regions cultivated capabilities, which can be defined as inter-organizational abilities, of extra-local learning. The regional form of learning in Minas allowed for the historical cultivation of capabilities to learn from extra-local knowledge in ways that the organizational enclave in Cochabamba case did not permit. This suggestion that the governance of learning shaped capabilities to absorb extra-local knowledge contrasts with investment-based explanations of

[38] The relations between the leadership of the Belén Station and the community in which it was located became tense, and in December of 1953 the technicians left the station and it was taken over by the community.

[39] Heilman also raises the questions of whether the elitist quality of the SAI was perhaps due to foreign training itself, in relations with campesinos in the era of the Bolivian revolution, although he does not develop this suggestion (Heilman 1982, 76-77).

absorptive capacity where prior investment determines the ability of regions to learn from the knowledge of mobile scientists. In Minas, in 1956, the new President of Brazil, Juscelino Kubitschek created a plan to expand the ACAR program nationally and the Government of Minas also requested support for the training of agricultural personnel from the ETA in the late 1950s and early 1960s (Minas Gerais Congress 1961). In 1957, five years after the revolution, the issue of local agricultural scientists and technicians rose to the level of the President of Bolivia, Siles Zuazo, who argued in negotiations with the United States over an economic plan argued that the shortage of qualified technicians hampered his ability to increase agricultural production by smallholders in an era of rising inflation when the country was relying on many agricultural imports to meet demands for food and in which the resale of food donations from the United States was undercutting local markets for production (DOS 1988b, DOS 1988a). In 1958, the President issued an executive order that sought to account for staff of agriculture and all of the other various Inter-American Services (Bolivia President 1958). In a letter in 1959, the Minister of Agriculture, Jorge Antelo, wrote to the Director of the SAI to strongly critique the autonomy of the SAI training programs for agricultural scientists stating that:

> the selection of Bolivian personnel and the determination of the type of training to which they will be sent abroad is a matter not only for the present but also for the future (MAGC 1960, 25).

When the SAI leaves the country, asked the minister, “what will happen with the Bolivian personnel of which the government has absolutely no knowledge nor knows the objectives for which they were trained… and how can they be incorporated in the Government… if [it] has not participated at all in the selection of individuals and training in accordance with its own economic plans (MAGC 1960, 25)?”

The letter from Antelo to Spaulding gave cover of ‘local control’ to the United States to jettison the SAI and to sacrifice the build-up of human capital for a mounting behind-the-scenes

administrative and ideological reorganization of the role of the United States more generally in Bolivia.[40] In the words of Andrews, Washington ordered the arbitrary dumping of SAI "apparently without plans and without warning." This caused a collapse in the organization and was a disaster for the organization at a particularly critical juncture. This destroyed the knowledge that had been built up through processes of circulation of scientists from Cochabamba within the organization of the SAI. The extension service cut over 70% of its staff, from 36 offices and 115 staff. In 1960 and 1961, and was forced to rely on donations of salaries from farmers. In 1962, there were 37 agents of high quality holding a Bachelor degree in agriculture or better, 11 home agents, and 6 field crop and livestock specialists in the extension organization. In 1962, the La Tamborada experiment station was transferred to the University of Cochabamba but the University was unprepared for this management and research activities were reduced because of lack of a lack of budgets, with no additional funds provided by the University, and relying primarily on available money that could be found in the general budget of the Ministry of Agriculture. Specialists left and nearly all of the trained Bolivian agriculturalists left the program for higher paying jobs either abroad or in the private sector in Bolivia. Andrews notes the lack of coordination of learning with the university after the transfer, as idiosyncratic individual efforts "rather than a structured or designed system of feeding the knowledge gained from testing and experimentation into the educational structure." Andrews argued that from 1952 to 1962 that "there has been a colossal waste of effort, time, and money here in the past 10 years because good things were started but after a year or two they were discarded for the bright ideas of somebody else. Continuity in personnel, purpose, and plan are essential if past efforts are to pay off (Andrews, Myrick, and Samson 1962). Andrews argued that "higher education is the critical issue right now" (Andrews, Myrick, and Samson 1962).

[40] On the background to the genesis of the Alliance for Progress in Bolivia, see (Field 2014). The Thorpe mission in 1961 recommended a tighter rein on the purposes to which US financial assistance was spent in Bolivia. In the beginning of the 1960s, the U.S. shifted towards a military assistance strategy in Bolivia as part of the Cold War.

This breakdown in the formation of processes of extra-local learning preceded the creation of the Bolivian Institute for Agricultural Technology (IBTA) but through a very different set of conditions than that in the case of Minas and Brazil. These processes provided an unstable foundation for the creation of IBTA in the early 1970s, In 1974, as a proposal for the creation of IBTA was waiting in the office of the President, the quantity as well at the quality of scientists was in a slide, with the number having fallen 27% since 1968 and the level of technicians with graduate training fell from 85% to 27% over the same time period (Riera and Barja 1974). In 1968, the budget for the Ministry of Agriculture was limited and there was a loss of management and technicians beginning in 1968, due to decrease in salaries, lack of facilities, and instability due to political situation, with lots of turnover, and unable to retain trained technicians (Malloy and Thorn 1971, Riera and Barja 1974).

The case of Humberto Gandarillas can help to demonstrate this trajectory. He noted that when he was at the University of Minnesota that the director of the experiment station offered him genetic lines in order to construct crosses of chickens but that he had to refuse the offer. He stated that leading world producers guarded their secrets in the lines that they crossed to avoid competition in the same ways as is done with hybrid corn, but that one scientist when he was in Minnesota, presumably because of the relationship made possible by Gandarillas' co-location at the University of Minnesota, offered to give him the genetic material in order to continue working on this at La Tamborada but that he couldn't accept because at that moment there wasn't anyone at home that could take control of such a project and that possessed the theory and practical experience necessary. He stated that with the passage of time, "with the transfer of La Tamborada to the Agronomy Department of the University of San Simón, both Chile and Brazil now produce hybrids. If the University of Cochabamba would have maintained leadership it would have been in the same position (Gandarillas 2001, 98). The circulatory system of agricultural innovation in Cochabamba was unable to build capabilities in the acquisition of extra-local knowledge search.

There was a considerable continuity of individuals that had engaged in extra-local mobility and/or been associated with ACAR in Minas or elsewhere into the group of actors that founded EMBRAPA.[41] We can interpret that part of the capabilities of EMBRAPA represented an ability to obtain knowledge from extra-local sources as part of a local system of innovation rather than, for example, the more common explanations of these connections of the founding of EMBRAPA in terms of purely endogenous origins nor, from an opposite view, the hegemony of the United States in the creation of EMBRAPA. These agents, who authored the foundational document of EMBRAPA, suggest as much in stating that one of the influences of the creation of EMBRAPA was the "*the experiences lived by other countries in the considered fields* (EMBRAPA 1972, 24)." In other words, actors from EMBRAPA selected and extracted and learned from experiences from other distant locations that centered on the locations that they best new from their experiences of multi-dimensional learning in distant locations.

This section uses this period beginning in the early 1960s to conceptualize extra-local learning by local systems in the tropics as part of longer-run historical process that shaped outcomes of the formation of *capabilities of extra-local knowledge search* as part of agricultural innovation. In Minas Gerais, the 1960s represented a culmination since the 1920s and 1930s of learning from extra-local knowledge that would feed into the creation of the education and training program of EMBRAPA after 1970. Entering the 1960s, the long-distance circulation of local scientists from the system of agricultural education, research and extension projects in Cochabamba had not only experienced discontinuities but it also effectively collapsed. Despite, surface similarity in the timing and organizational blueprints in which authoritarian governments in

[41] Edmundo da Fontoura Gastal, who was an agronomist with a degree in agricultural economics from Viçosa later held positions in in ASCAR in Rio Grande do Sul and elsewhere, and was based in Chile and at the Alberto Boeger Research Station, La Estanzuela in Uruguay as a regional advisor for IICA. Otto Lyra Schrader, who possessed a degree from Vicosa, completed training between 1940 and 1941 in horticulture, plant pathology and soils at the School of Agriculture at the University of Florida, as noted in IIE. Cliber Vieira who studied at Viçosa, and then at University-Davis in 195X and who worked for AIA in extension in Santa Rita dos Passos. Moacyr Maestri who studied at Viçosa, and who received a Rockefeller grant from 1955-57. Irineu Cabral, had been the Director of the Bank of the Northeast of Brazil (BNB) that was responsible for the transfer of the ACAR model to states in the northeast.

both Brazil and Bolivia created national agricultural research organizations, the very different circulatory systems of Minas and Cochabamba shaped the capabilities of extra-local knowledge search of these two organizations. The continuity of staff from the experience of Viçosa and ACAR in Minas, and the ability to learn from and critique that experience shaped the creation of EMBRAPA while the almost total loss of staff from the extension organization hindered the creation of capabilities at the moment of the creation of IBTA. The findings from the regional governance of the two cases suggests the need to revise explanation base on organizational autonomy as a source of success in agricultural innovation in the existing literature on national research organizations.

CONCLUSION

This study claims that agricultural scientists and other knowledgeable individuals from the tropics have always used mobility to produce knowledge through multiple scales but that scholars have rarely explained the socio-technological and political-ecological conditions through which these processes changed tropical agricultures over space and time. The findings from historical cases of mobility from two subnational regions in South America in the early 20th century help to recast processes of spatial mobility from South America as a more significant but also more conditional factor in the making of tropical agriculture over time.

The main finding of this study is that regions of Minas and Cochabamba exhibited different processes of mobility of agricultural scientists over time mediate the extent to which regions acquire, absorb and apply extra-local knowledge as an ongoing but changing set of processes over time rather than the existing explanations of mobility in terms of single discrete stages of formal education in scientific principles. The first finding from the cases of São José and Cárdenas in periods prior is that this learning emerges from the actions of local agents in the tropics and is

inter-relational in ways that help us to explain the multi-dimensional social nature of learning beyond the laboratory in ways that analysis of the prior plans of local or United States-based actors for agricultural modernizations cannot. The second finding is that differences in the regional governance of extra-local learning mediated the contribution of mobility of agricultural scientists to learning in ways that mechanistic stage-based models, organizational plans or the simple aggregation of the accumulation of human capital cannot explain. The third finding of the inter-relational nature of learning between actors over time helps to build a basis for explanations of the inter-temporal construction of capabilities in the case of Cochabamba case missed the potential to contribute to a key moment of the making of institutions of agricultural services but that the case of Minas endured over time and contributed to the foundations for the founding of EMBRAPA.

These findings also have implications for current debates at a moment of uncertainty as scholars and policymakers grapple to explain multi-scalar processes of governance of agricultural innovation in a complex moment of climate change in the tropics. The inclusion of the circulation of knowledgeable individuals from the tropics alongside plant things and returning foreign visitors from the tropics opens new questions on how local scientists conceptualized, chose, appropriate, challenge, learn from, coordinate, and collaborate in ways that shape the way that new knowledge is recombined and shapes knowledge at home. The finding of the regional unit as the basis of learning from extra-local technology provides a corrective to literature that has privileged the organization as the unit of explanation of learning from extra-local ways, and which forms the basis of explanations of EMBRAPA. These findings from South America and the broader explanatory framework of mobility from the tropics suggest the need for a broader research program that improves our ability to explain mobility in ways that cut between broad mechanistic theories of global diffusion but also understand the role of different socio-technological and political-ecological patterns at play beyond single case studies of mobility.

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Chapter Three. Moving to Peripheral Fields of Agro-Innovation: Mobility, Variety and the Emerging Geography of Tropical Knowledge in South American Agro-Industries

INTRODUCTION

Since the late 1990s, scientists from locations in Brazil and other so-called emerging economies of China and India produced dramatic growth in knowledge bases for innovation in agro-industries and environmental services (Leydersdoff and Zhou , Cañas-Guerrero et al. 2013, Ponomariov and Toivanen 2014). The question that remains largely unexplained is how the geography of scientific activities at subnational and supra-national scales influenced outcomes of learning and innovation. The present paper addressed this question by examining the spatial mobility of scientists employed by the Brazilian Agricultural Research Corporation (EMBRAPA), a public research institute specialized in tropical agro-industries that was a leading driver of the three thousand per cent increase in the production of agricultural and environmental knowledge in Brazil since the late 1990s (Penteado Filho and Avila 2010, Cañas-Guerrero et al. 2013, 25, Fink et al. 2013, OECD 2015). These scientists are interesting cases for analysis of geographical shifts in agro-innovation because they base their work in over fifty different subnational locations in Brazil and have recently extended cross-border activities to locations across seventy-seven countries from Antarctica to Afghanistan that lay beyond the established centers of agricultural science in the United States and Europe. The present study examined new evidence from multi-sited fieldwork in South America and novel linked datasets on mobility, articles and inventions in

order to integrate “peripheral fields” of knowledge production in the world region of Latin America into a more robust geographical explanation of agro-innovation by scientists from Brazil.[1]

Two thousand doctoral-level scientists and seven thousand technicians from EMBRAPA specialize in an array of agro-industries and enviro-services that shape innovation in tropical agro-industrial systems (Stads and Beintema 2009, Beintema, Avila, and Fachini 2010). The activities of these scientists in Latin America and Africa remain incipient in comparison to traditional collaborations in the United States and Europe but require closer analysis because these world-regions represent the greatest tropical interface between lands slated for agricultural expansions and 1.2 billion hectares of forests that mitigate climate change (Alexandratos and Bruinsma 2012, 106, Keenan et al. 2015, 11). Over the last decade, analysts began to call attention to “south-to-south” activities of EMBRAPA scientists as consultants in technical assistance projects that the Brazilian government provided to governments in developing economies from Bolivia to Benin and beyond (Economist 2010). However, as the new empirics in the present study attest, these cases of technical assistance represent just a fraction of the activities of scientists in developing economies and our existing scholarship has only just begun to explain the larger geographies of knowledge and innovation that these express. The present study addresses this gap by asking the question: what explains the activities of EMBRAPA scientists in Bolivia and Latin America and how do these world-regional findings help to explain the effects of scientific mobility on the wider production of knowledge in agro-industries and associated enviro-services?

Existing approaches and national-level metrics of technological change in agricultural production do not fully capture the intersecting social, sectoral and ecological systems that shape dynamic geographies of knowledge and innovation in tropical agro-industries. Analysts have begun to examine the international policy and politics of foreign aid as well as the political economies of agribusiness that embed the technical assistance activities of EMBRAPA scientists in Latin America and Africa but this literature has not examined the implications that these have for

[1] The term Latin America refers to South America, Central America, Mexico and the Caribbean in this paper.

outcomes of knowledge flows and innovation (Aoki Inoue and Costa Vaz 2012, Scoones et al. 2016). Agricultural economists have used agronomic models to map the potential for spatial spillovers of biological technologies for agricultural production but the basis of these models in the similarity of factors such as soil composition and rainfall averages do not help to explain knowledge flows across a broader set of agro-industries and enviro-services nor the dynamic social and ecological processes that also mediate knowledge spillovers (Alston , Pardey, Wood, and Hertford 2010). Analysts of regional systems of innovation have made analytical strides by parsing relations between individual EMBRAPA scientists and other heterogeneous agents of agro-innovation at subnational scales but these approaches do not extend to the extra-territorial activities of these same scientists that move beyond their home regions in Brazil as part of their scientific endeavors (Ekboir 2003, Spielman and Birner 2008). These literatures address aspects of the activities of EMBRAPA scientists in Latin America but new frameworks are required to explain the socio-technological and socio-environmental basis of knowledge spillovers between innovative agents and subnational places in tropical agro-industrial systems.

This paper constructs a geographical framework of learning and innovation in tropical agro-industrial systems in Brazil that builds on new approaches that suggest that the effects of mobility on knowledge flows are more multi-dimensional and multi-directional than traditional frameworks of “brain drain” versus “brain gain” (Saxenian 2005, Agrawal, Cockburn, and McHale 2006, Saxenian 2006, Alesina, Harnoss, and Rapoport 2016). The present study advances the state of the debate on knowledge in agricultural production systems by building on geographical literature on regional industrial systems that suggests that different types of social and institutional proximities may allow scientist-inventors to learn from spillovers of knowledge across space (Morgan and Murdoch 2000, Bathelt, Malmberg, and Maskell 2004, Boschma 2005). The first level of analysis of the present study builds up from the ground by conducting multi-sited fieldwork that followed EMBRAPA scientists to locations in Bolivia and Latin America in the capacity of scientific consultants in “south-south” technical assistance projects. The second level of analysis explored a novel global dataset that linked travels of EMBRAPA scientists to indicators of knowledge and

inventions between the years 2000 and 2014 in order to construct a general framework of the effects of extra-local mobility of scientists on knowledge flows and innovation. This study provides a more granular view of the geography of knowledge than existing organizational biblio-metrics on foreign collaborations of EMBRAPA scientists abroad and responds to the call by Brazilian scholars of innovation to move the debate on scientific mobility by examining broader set of logics, tacit knowledges, and social relations of scientific production that shape innovation (Velho 2001, Penteado Filho and Dias Avila 2009b, Yumi Ramos and Velho).

This paper argues that the mobility of tropical scientists from Brazil to a broader set of locations of knowledge production in Latin America serves as a mechanism for the absorption of spill-ins of partially tacit knowledge that reduce uncertainty on the direction of socio-technological and socio-environmental change in tropical agro-industries. The interactions with people and places in Latin America that is possible through mobility provide access to a broader spectrum of localized knowledge that can then be potentially used for innovation in home regions in Brazil. The *variety* of institutional and social arrangements of knowledge production across subnational regions of Latin America is thus a potential source of attraction to scientists from regions in Brazil rather than only a *friction* as in most existing models of trans-border technology flows. This paper uses data on the composition of knowledge flows in cross-border knowledge production to suggest that mobility to Latin America may be most relevant as a source of learning in less-structured production networks of agro-industries and environmental conservation at formative moments in time. These findings re-cast “technical assistance” activities in a broader framework of learning and contribute new insights on the multi-local dimension of “local” agents in regional systems of innovation within Brazil.

This paper proceeds by reviewing existing explanations of the cross-border geography of EMBRAPA scientists and then building on new debates over scientific mobility and knowledge spillovers to construct a conceptual framework of the mobility of EMBRAPA scientists as a mechanism through which home regions in Brazil learn from location-based varieties of knowledge

in Latin America. The first empirical section argues that the growth of the global mobility of EMBRAPA to “peripheral” locations in the Americas serves as a source of knowledge for EMBRAPA scientists and home regions in Brazil. The following section interprets mobility as a source of varied multidimensional knowledge flows through which EMBRAPA scientists learn from know-how in Latin America as part of innovation at home. The final section examines the composition of mobility, patents and knowledge products in order to illustrate the peripheral pathways of learning expressed by these inter-regional geographies.

EXPLAINING THE GEOGRAPHY OF SCIENTISTS AND AGRO-INNOVATION IN BRAZIL

Policy and Politics of Foreign Agricultural Assistance

Over the last decade, analysts have primarily interpreted the global activities of EMBRAPA through frameworks of “emerging donors” of international development policy and the political economy of foreign agricultural aid but these approaches do not explore the implications of these processes for knowledge flows nor innovation. This early literature on “south-to-south” cooperation initially emphasized the charitable and “horizontal” nature of EMBRAPA scientists in terms of a transactional “transfer” of knowledge from Brazil to other governments of developing economies in Latin America and Africa. Analysts of foreign policy have revised the view of EMBRAPA by arguing that transfers of knowledge to other governments serve as an instrument of foreign policy outcomes of the Brazilian president or foreign policy establishment (Aoki Inoue and Costa Vaz 2012, Batista Barbosa 2012, Burges 2014). Analysts of the political economy of agriculture in Brazil have also begun to examine the activities of EMBRAPA in light of the interests of Brazilian

agribusiness and land acquisition in the developing world, particularly in the large Prosavana project in Mozambique (Scoones et al. 2016). These works have helped to situate EMBRAPA in larger policies and political economies of the Brazilian government and business interests but this literature has not examined the activities of EMBRAPA in Latin America in terms of the acquisition of knowledge for innovation. The present paper explores more closely the activities of EMBRAPA consultants in Latin America and Africa and helps to re-cast the existing literature on the mobility of these scientists in terms of a broader logic of the inward absorption – as opposed to merely the outward transfer - of knowledge.

Sectoral Models of National and Regional Innovation

The existing approaches to innovation in the agricultural sector help to explain different facets of innovation in Brazil, and to a lesser extent in subnational regions of Brazil, in which EMBRAPA scientists base their work but these frameworks do not conceptualize inter-relationships between innovative processes in different spatial units across national borders as a factor in the production of knowledge and innovation. The most common explanation of agricultural innovation in Brazil or Brazilian states in terms of indicators of public investment into formal research and development (R&D) activities help to explain factors such as the maintenance of high level of human capital of EMBRAPA scientists but has little to say about the more particular activities of scientists nor the ways that they collaborate with other innovative agents across space (Stads and Beintema 2009, Beintema, Avila, and Fachini 2010). Induced innovation approaches introduce institutions into the economics of technological change but the movement of innovative agents such and knowledge between locations in Latin America and Brazil are exogenous to these models in which underlying factor endowments in a discrete spatial unit determine processes of institutional change (Ruttan and Hayami 1984). Approaches to regional systems of agricultural innovation have brought important conceptual advances to the interaction

between individual EMBRAPA scientists and other heterogeneous agents in the institutional arrangements of a subnational region of Brazil but these frameworks do not consider the multi-locational nature of such scientists as a dimension of more “local” processes of agro-innovation (Ekboir 2003, 582, Spielman and Birner 2008). The framework developed in the present study seeks to extend these approaches from regional systems of agricultural innovation to include the extra-territorial mobility of “local” innovative agents from Brazil as part of the collaborative processes of learning that shape agricultural innovation.

Spillovers through Agronomic Similarity

Agricultural economists developed spillover models that conceptualized, and sought to evaluate, generally *ex ante*, the potential for spillovers of technology across the borders of nations such as Brazil from public research systems in other nations or multilateral research organizations in the context of declining investment into the international research system since the 1980s (Byerlee and Traxler 1997, Johnson and Evenson 1999, Evenson , Alston 2002). More sophisticated specifications of these models use similarity in agronomic and ecological variables across different countries and regions of Brazil and Latin America in order to more finely map spillover potential in commodity crops but the agronomic focus of these models suggest that these may not travel well to agro-industrial sectors and process innovations beyond spillovers of seed germplasm (Pardey, Alston, and Ruttan , Pardey, Wood, and Hertford 2010). An additional and more general limitation of these models is the tendency to base spillover projections on the assumption that knowledge will tend to flow freely across any spatial distance and to treat institutions, social systems and non-market environmental services as “frictions” or exogenous to knowledge spillover maps (Byerlee and Traxler) Pardey, Wood, and Hertford 2010a)(Pardey, Alston, and Ruttan, 973). These global models help to map spillover determinants in Latin America that associated with the agro-climatic specificity of certain biological aspects of agricultural

production but have little to say known about the social mechanisms of spillovers that not only mediate – but also facilitate - the actual geography of knowledge flows in tropical agro-industrial systems. The present paper addresses this gap by examining mobile EMBRAPA scientists as social mechanisms of spill-ins in order to expand our understanding of the socio-technological and socio-environmental aspects of knowledge spillovers in tropical agro-industrial systems.

Collaboration Metrics of Brazilian Science

A small but growing set of metrics demonstrate the role of EMBRAPA in knowledge and innovation in Brazil but there are few empirics and almost no theorization of the sub-national and extra-national dimensions of processes through which these scientists learn and innovate (Leta, Glänzel, and Thijs 2006). Penteado Filho and Dias Avila use bibliometric data from 1997 to 2006 to argue that co-authorship by EMBRAPA scientists at global scales is limited and tends to concentrate in the United States and Europe due to the existence of virtual collaborations with foreign laboratories (Labex) in these countries (Penteado Filho and Dias Avila 2009b). These and authors have begun to examine biblio-metrics at the level of disaggregated units of EMBRAPA in Brazil but explanations of the geographical dynamics of proximity and collaboration in knowledge flows at the subnational level in Brazil – and how these relate to global-scale collaboration – has only recently begun (Gonçalves and Almeida 2009, Mena-Chalco et al. 2014, Sidone, Haddad, and Mena-Chalco 2016) (Penteado Filho and Cabral de Sousa Dias 2008, Penteado Filho and Dias Avila , Penteado Filho and Dias Avila , Lima, Velho, and Lopes de Faria 2010). The use of patent data and examination of knowledge spillovers in agro-industries in Brazil remains almost completely unstudied beyond a handful of studies that use United States patent data (Gonçalves and Almeida 2009, OECD 2015, 123-25). The present paper therefore responds to the call for more scholarly explanations of the global geography of Brazilian scientists by building a more explicitly spatial framework and set of novel new empirics on the mobility, knowledge production

and inventions of EMBRAPA scientists through a case study of Latin America world region (Velho 2001, Yumi Ramos and Velho).

Mobile Scientists and Spillovers in (Agro-)Industrial Systems

This paper constructs this framework by building on more theoretically-oriented set of geographical debates on the knowledge spillover effects of mobility in in industrial sectors beyond agricultural production. Theorists of innovation high-technology sectors suggest that the spatial circulation of knowledgeable individuals from emerging economies facilitates multi-directional flows of partially-tacit knowledge across distant locations (Saxenian 2005, Saxenian and Sabel 2008). There are unsettled debates over the relational and spatial proximities that may mediate different dimensions of knowledge spillovers across distances but also a line of analysts that suggest that even short-term mobility such as that of EMBRAPA scientists in Latin America may facilitate learning at home in home locations in Brazil (Boschma 2005, Torre 2008, Fitjar and Huber 2014, Alesina, Harnoss, and Rapoport 2016). Relevant insights from these debates in broader set of industries can help to broaden and deepen the smaller body of work on spatial spillovers of knowledge in agro-industrial systems in the tropics (Morgan and Murdoch 2000, Ingram and Morris 2007, Ingram, Fry, and Mathieu 2010, Klerkx and Proctor 2013). As part of this study of EMBRAPA scientists in Latin America, this study draws on these different threads of literature to build a new framework of the knowledge spillin effects of the mobility of EMBRAPA scientists.

Conceptual Framework

This paper constructs an explanatory framework of the spatial mobility of EMBRAPA scientists as a mechanism for the absorption of localized knowledge from other subnational "host" locations in Latin America that expands the variety of knowledge for innovation in tropical agro-industrial systems in "home" regions of Brazil.[2] This framework integrates the logic of mobility to Bolivia and Latin America into a more global geographical explanation of scientific mobility by conceptualizing the advantages of two "peripheral fields" expressed by these processes: *locations* of knowledge production outside of the centers of traditional global sites of advanced agricultural science organizations, and *dimensions* of knowledge beyond codified transfers and bureaucratic plans for scientific activities.[3] This framework conceptualizes social and institutional differences particular to subnational locations as a source of a partially-fragmented pool of knowledge that varies from knowledge available in subnational locations in Brazil. Mobile EMBRAPA scientists are a mechanism for learning from spill-ins of such knowledge, defined broadly as informal exchanges of a spectrum of partially-excludable knowledge not detailed through a transfer agreement, because mobility allows scientists to relate to other innovative agents (face-to-face) and environments of knowledge production (face-to-place) in these locations.

[2] In this paper, an agro-industrial system refers to industries and services (environmental and other) that interface with agricultural production networks as well as the territorial factors (e.g. social relations, agrarian institutions and political-ecologies) that shape these economic activities.

[3] This paper moves from the common usage of the tern "periphery" as equivalent to the "developing world" of the globe toward a finer-grained conceptualization of differences in territorial and organizational factors that influence agro-innovation at the subnational level between regions.

Research Design

This research constructs an explanation of difficult-to-observe knowledge flows between subnational locations+ in Brazil and Latin America by "following" processes of mobility of individual EMBRAPA scientists in relation to other agents of agro-innovation in Latin America (Latour 1987, Peck and Theodore 2012). This study worked outward from a case study of EMBRAPA scientists as consultants for technical assistance projects in Bolivia to a wider level of analysis of scientific mobility at the level of the world region of Latin America. The study conducted semi-structured interviews with scientists, administrators, and associated government ministries across multiple sites in Brazil and Bolivia in order to examine the logics, interests and practices of cross-border knowledge relations between locations. The study constructed a novel *EMBRAPA mobilities* dataset from the federal register of Brazil in order to examine the location and composition of activities of 3,424 episodes of mobility of EMBRAPA employees to Latin America since the year 2000.[4] This study explored the relationship between mobility and knowledge flows at the level of the individual scientist by linking the mobilities data to new databases of patents and knowledge products that the author constructed from Brazilian and global patent data as well as bibliometric records from the Elsevier Scopus database.[5]

[4] This study matched names against EMBRAPA sources and the Government of Brazil's Lattes database, manually and through a parsing script developed by Mena-Chalco and Marcondes Cesar Junior (2009). On the "names game" associated with this matching, see Trajtenberg, Shiff, and Melamed (2006)

[5] Scopus results were similar to the magnitude of results obtained by the Thomson Reuters Web of Science (WoS) index and greater in number than the Scielo index that specializes in Portuguese and Spanish language publications. Scopus and WoS provide the best globally comparable and publically-available evidence but also count only thirty per cent of the total knowledge production in the internal evaluation system of EMBRAPA (Penteado Filho and Dias Avila 2009b). In light of this limitation as well as the more general issues concerning articles and inventions as indicators of knowledge and innovation, the evidence in this study explores what it likely to be a wider set of unobserved knowledge flows and innovation.

MOVING BEYOND CORE LOCATIONS: MOBILITY AND LEARNING FROM LATIN AMERICA

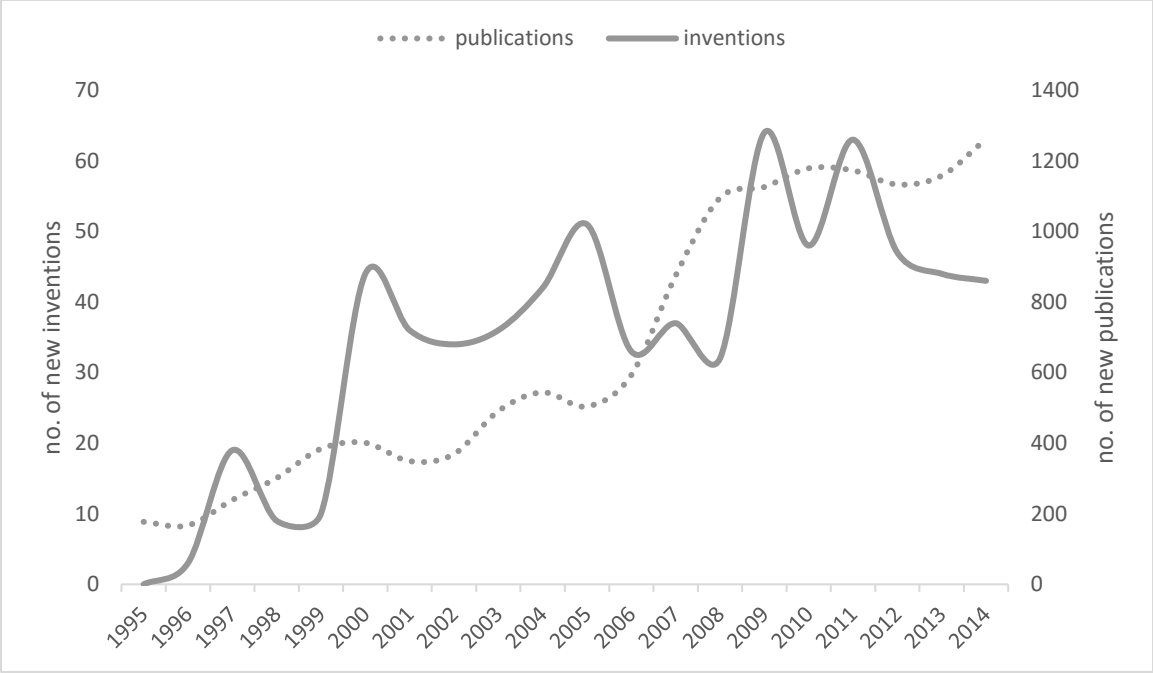
After the meeting between Presidents Morales and da Silva in Brasilia in 2007, EMBRAPA scientists flew from Brasilia to La Paz and other locations in Bolivia to provide consulting to that's country's government on the founding of a new public research institute. What explains these activities and others like them that EMBRAPA scientists increasingly conducted in Latin America as well as Africa since the turn of the century? The basic parameters of existing explanations have been set by debates over foreign aid policy and the extent to which this "assistance" was charitable as opposed to self-interested. There appears to be evidence in support of both views. However, this paper lays out a different argument that approaches these activities as cases of a more general phenomenon of scientific mobility and examines their causal effects on knowledge and innovation by EMBRAPA scientists in Brazil rather than cleaving these off into a separate discussion around foreign aid. The present section uses new evidence to construct a framework of mobility and suggest that EMBRAPA scientists express a latent demand for knowledge from "peripheral" locations in Latin America that produces effects that can be viewed in terms of the absorption of knowledge spill-ins.

Moving to Peripheral Locations and the Production of Knowledge in Brazilian Regions

This paper stakes out the argument that scientific mobility is a causal process that helps to explain the geographical production of learning and innovation by EMBRAPA scientists for use in their home regions in Brazil. Prior to examining new evidence of mobility, we can first briefly review aggregate outcomes of learning and innovation by EMBRAPA scientists. Figure 3-1 presents data from 1995 to 2014 on new publications in the Scopus index that were authored by

EMBRAPA scientists, and new applications for patents or plant cultivar protections by EMBRAPA that were invented by scientists from this organization.[6]

Figure 3-1 Production of Knowledge and Inventions by EMBRAPA Scientists, 1995-2014



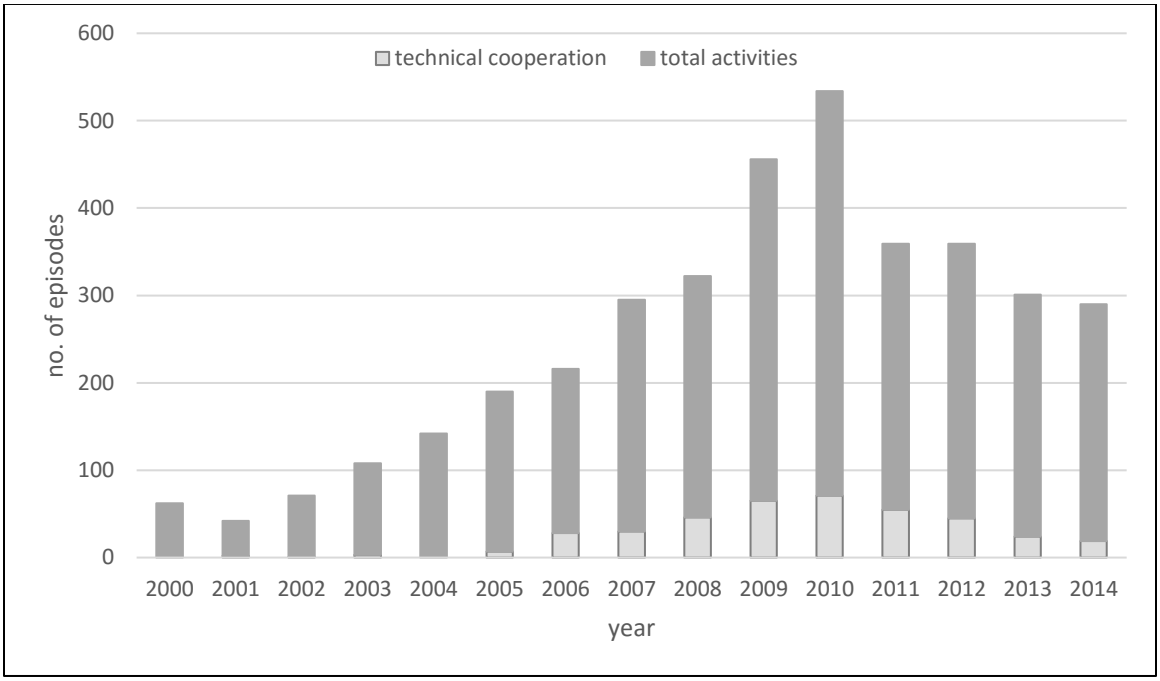
Sources: (INPI , Elsevier , SNPC 2016, WIPO 2016)

National indicators such as those for public investment in the education and salaries of doctoral research scientists are established factors in this growth but are only partially sufficient to explain the geographical production of these outcomes across both local and global spaces (Viotti and Baessa 2008, 32, Stads and Beintema 2009, NSF 2015). Improving our understanding of the

6 This paper approaches publications and inventions as partially-overlapping indicators of learning in non-linear innovation processes as opposed to a sequential chain in which scientific publication precedes an invention-as-innovation (Fleming 2001, Murray 2002, Nelson et al. 2014). Results from Scopus are nearly identical to the Thomson Reuters Web of Science (WOS) index and greater in number than the Scielo index that specializes in Portuguese and Spanish language publications. Scopus and WOS provide the best globally comparable and publicly-available evidence but also count only thirty per cent of the total knowledge production in the internal evaluation system of EMBRAPA (Penteado Filho and Dias Avila 2009b).

mobility of EMBRAPA scientists therefore helps to build a more robust and spatially explicit explanation of this growing knowledge base fr gro-innovation.

Figure 3-2 Magnitude of Mobility of EMBRAPA Scientists to Latin America, 2000 to 2014



Sources: (EMBRAPA)

Notes: an episode is defined here by the start date of mobility in the year, although a small portion of longer trip or trips made at the end of one year will continue in the following year

New evidence of the spatial mobility of EMBRAPA scientists to "peripheral" global location helps to build a more robust explanation of mobility as a factor that helps to explain the production of knowledge and production by EMBRAPA scientists. A new *EMBRAPA Mobilities* dataset of nearly 10,000 trips that the author constructed from EMBRAPA directives published in the federal register of Brazil provides the first evidence of the mobility of EMBRAPA scientists and technicians to Latin America over the period when EMBRAPA scientists produced increasing knowledge and inventions. Figure 3-2 presents the yearly total of 3,424 mobility episodes to Latin America between the years 2000 and 2014 as well as the share of these that were associated with

consulting for the technical cooperation agency (ABC) of Brazil's Ministry of Foreign Relations. As a corps, EMBRAPA scientists increased their mobility to Latin America from sixty-three episodes in the year 2000 to 183 in 2005 and then to 463 in the year 2010. In a context of economic and political uncertainty since the year 2010, this yearly total decreased but in 2014 still represented a nearly three-fold increase in comparison to the year 2000.

Moving beyond Foreign Assistance

The broader framework of scientific mobility moves analysis beyond the limits of the debate over foreign assistance and towards a new understanding of the logics of scientists in motion. The technical assistance series in Figure 3-2 provides a new look at technical assistance projects of the Brazilian Cooperation Agency (ABC) from the perspective of the mobility of EMBRAPA scientists. This evidence demonstrates empirically what analysts have already suggested was an increase in the role of EMBRAPA as consultants for such technical assistance projects to Latin America and Africa over this period. The more significant finding from this set of empirics is that such consulting missions for the ABC only accounted for between six per cent and twelve per cent of the mobility of EMBRAPA scientists to Latin America over the period of the most significant increase in technical assistance projects between the years 2000 and 2010. Mobility incorporates all activities in peripheral locations rather than theorizing from the small subset of activities associated with ABC projects.

The framework of mobility problematizes the existing bureaucratic distinction between "scientific learning" on one hand, and the provision of technical assistance on the other hand. One scientist at EMBAPA with knowledge of the cross-border activities of the organization's scientific corps explained technical assistance activities to governments such as those in Bolivia and the developing world could be explained as the least important of three priorities of EMBRAPA at global scales, with activities to support to agro-industrial firms from Brazil in second position, and

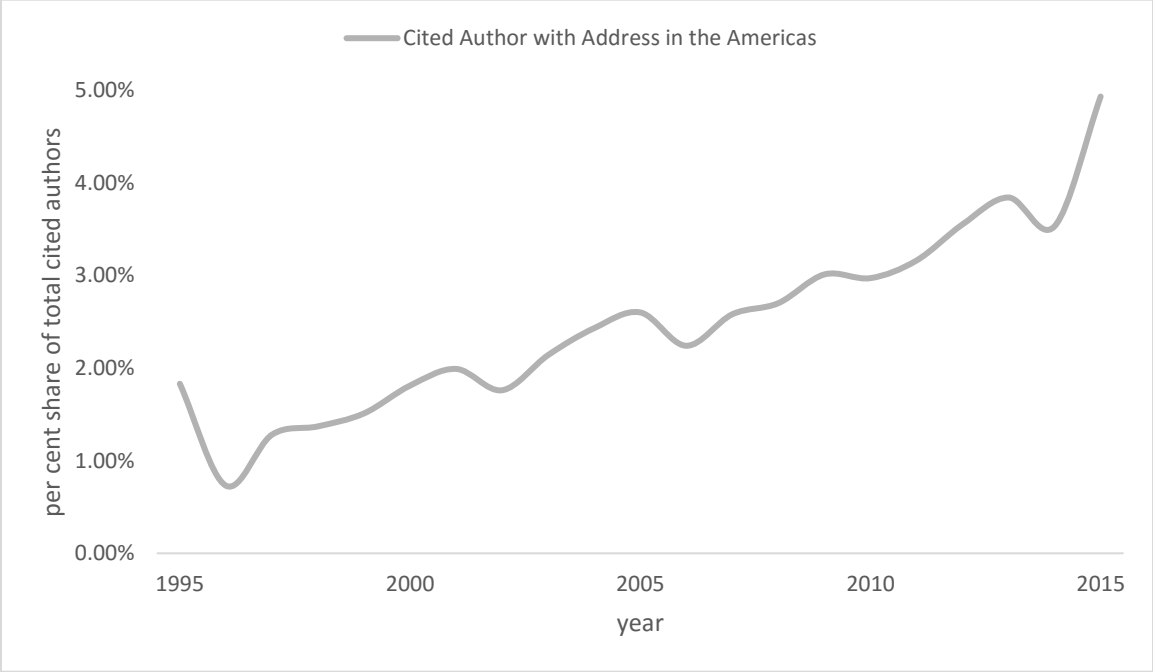
science at the innovation frontier by far outstripping other concerns. EMBRAPA distinguishes between technical assistance activities and other capacity-building activities that seek to “reduce poverty and hunger and advance social, economic, and environmental development” in the developing world and, on the other hand, scientific cooperation with prominent international organizations and foreign co-laboratories (Labex) such as the United States Department of Agriculture that aim to “broaden research horizons” by a “continuous exchange of technology and knowledge.” These comments stressed the “core” business was the production of knowledge for innovation but the comments on the provision of technical assistance still leaves the analyst grasping for a sufficient framework through which to explain these and other activities in the “periphery” of locations such as those in Latin America and Africa. These individuals are mobile scientists. There were 206 inventors that traveled to Latin America over this period. Inventors traveled an average of between three and four trips during this period. This represents a total of 657 trips, or approximately 25% of episodes of mobility over the studied period.

Mobility and the Absorption of Spill-Ins from Latin America

This evidence of increasing mobility to Latin America over a period of rising knowledge production suggests a latent demand by EMBRAPA scientists or other innovative agents in their home regions in Brazil for extra-territorial knowledge from locations in Latin America. Latin America world region accounted for thirty-six per cent of the total global travel of EMBRAPA scientists over the studied period. It would be unlikely for this region to account for such a significant share of mobility by these leading scientists if learning were not a significant benefit of such activities in Latin America. This learning by EMBRAPA scientists does not necessarily result from an organized plan for knowledge acquisition nor does it preclude concurrent transfers of knowledge to other innovative agents in Latin America, as in technical assistance projects. The

mobility of these scientists should, however, be approached as a causal factor in our explanations of learning by EMBRAPA scientists and their home regions in Brazil.

Figure 3-3 Citations of Knowledge from Latin America in Articles by EMBRAPA Scientists, by Share of Total of Cited Authors, 1995-2015



Source: (Elsevier)

The spatial mobility of EMBRAPA scientists is a causal factor in learning from a broader spectrum of knowledge that comprises informal knowledge spill-ins from Latin America.[7] Spill-ins are defined here in a broad sense as learning from knowledge that is assumed to be only partially-excludable and which is not detailed as a knowledge transfer in a legal or bureaucratic instrument or plan. The location of citations by knowledge authored by EMBRAPA scientists serves as a rough proxy for the geography of such spill-ins. Figure 3-3 presents evidence of the extent of knowledge citations in products authored or co-authored by EMBRAPA scientists from 1995 to

[7] Absorption here refers to a wider spectrum of learning through the filtering, assimilation and application of knowledge (Cohen and Levinthal 1990, Criscuolo and Narula 2008).

2015 in which the cited author was based in a location in Latin America. This data demonstrates that Latin America accounted for a modest share that steadily increased in importance over the course of two decades from the level of one per cent of citations in 1995 to approximately five per cent of citations in the year 2015.

This paper uses this evidence to suggest that the mobility of EMBRAPA scientists is a causal factor that helps to explain spill-ins of knowledge from Latin America to EMBRAPA scientists and their home regions. This claim of a causal relationship follows evidence from surveys with citers and cited patent inventors that found that decisions to cite could be attributed to social interactions such as direct communications, word of mouth, and the viewing of demonstrations or presentations (Jaffe, Trajtenberg, and Fogarty 2000). These authors also demonstrate that citations are quite noisy indicators of face-to-face interactions. This suggests that other mechanisms of knowledge flows such as, for example, changes in the quality or quantity of knowledge that may have emanated from Latin America over this period, also likely contributes to knowledge flows. However, we can also assume that citations only hint at a greater extent of unobserved knowledge spill-ins that are also related to mobility. The point here is that mobility is likely to be a key factor behind these processes, albeit one that needs to be untangled from other processes through additional research.

LEARNING BEYOND CORE PRINCIPLES OF AGRONOMIC SCIENCE: PLACE-BASED VARIETIES OF KNOWLEDGE

The woodland savannah of the South American *cerrados* biome stretches from Brazil's heartland of agricultural production in the center-west region of the country across the border into the eastern region of Bolivia and the city of Santa Cruz de la Sierra. This city was the sole location that EMBRAPA scientists visited in Bolivia in the year 2000. Over the last decade, the analytical

framework of similarity represents a sort of paradigm through which analysts and scholars explain the geographical distribution of EMBRAPA activities across Latin America and Africa. The primary example that many analysts use as an example of this similarity is the *cerrado* that stretches across the borders of Brazil to these regions and the way that this facilitates soybean production across space. Similarity in agronomic variables such as soil composition or climatic variables such as rainfall help to explain how core principles of biology constrain the flow of certain seed cultivars between specific types of places in Brazil and Latin America (Pardey, Wood, and Hertford 2010). However, this paradigm of similarity is less useful in explaining mobility to places such as Riberalta, Bolivia in the western Amazon or La Paz in the Andean highlands, nor forms of learning across a broader range of sectors that interface with primary production.

This section argues that a framework of inter-place variety as a facilitator of knowledge flows provides an analytical dimensions of the geography of activities that is lacking in the current literature. This section argues that the mobility of EMBRAPA scientists to varied subnational locations in Latin America is a social mechanism for the absorption of "peripheral" dimensions of knowledge that localize in particular relational and institutional arrangements. Analysts have begun to problematize the narrative construction of similarity at the national level between Brazil and other nations (Wolford and Nehring 2015). This paper argues for the need to move the debate beyond similarity and toward an improved understanding of how variation across subnational units serves as a source of positive effects on knowledge flows. This section uses data on mobility to conceptualize inter-locational variety – not merely similarity – between the "home" and "host" contexts as a source of learning by EMBRAPA scientists and suggests that this expresses the spatial spreading of innovation risk in tropical agro-industrial systems at home. This approach emphasizes territorial factors such as social, socio-environmental and industrial arrangements that shape knowledge spillovers in ways that extend beyond agro-climatic similarity for locationally-specific seed varieties. This section approaches mobility as a relational rather than a transactional mechanism for the absorption of knowledge from Latin America and builds a basic typology of mobility to Latin America in terms of relational platforms.

Learning beyond Similarity: Inter-Regional Variety as a Spatial Logic of Learning

Variation in localized knowledge bases between "home" locations of EMBRAPA scientists in Brazil and "host" locations in Latin America provide a more robust framework of knowledge flows and spill-ins than in the existing paradigm based solely on *similarity-based* knowledge spillovers. Diversification of knowledge can be understood as a second logic alongside specialization that attains importance as a way to reduce risk in a context of uncertainty on the direction of technological change in tropical agricultures that increasingly interface with a range of industries, political-ecologies and social relations (Goodman, Sorj, and Wilkinson 1987). As we move the debate from a focus on agronomic characteristics for primary production to a broader range of agro-industries and enviro-services that shape tropical agricultures, the concepts of related and unrelated "varieties" of knowledge among regional industrial geographers may serve as a theoretical guide to untangle the positive spillover effects of the diversification of knowledge (Frenken, Van Oort, and Verburg 2007). A recent high-level technological forecasting that EMBRAPA conducted argued that the "multi-regional, multi-sectoral and multi-thematic particularities" of innovation in multi-functional agricultures is expressed through a more diffuse set of "signals" to potential opportunities, challenges and risks (EMBRAPA 2013, 70)." In contrast to common explanations of EMBRAPA in terms of an established global plan for agro-innovation, interviews with key EMBRAPA scientists in 2014 also suggest the importance of uncertainty in explaining how this corps grapples to align a variety of activities across an array of locations in a way that fits with the primary goal of producing knowledge. The diversification of the scope of knowledge as an explanatory concept provides a more robust framework of the locational organization of cross-border activities than explanations based on locational similarity alone.

The mobility of scientists from EMBRAPA is a relational mechanism for the absorption of more "peripheral" fields of partially-tacit knowledge from people and places in subnational regions in Latin America. We can conceptualize partially-tacit dimensions of knowledge as practice-based

"know-how" and social "know-who" rather than the "know-what" of facts of agronomic science and the "know-why" of biological principles of explanation (Lundvall and Johnson 1994). Mobility is an important mechanism for absorbing know-how and know-who because it facilitates face-to-face interactions with a greater variety of innovative agents in Latin America as well as face-to-place interactions with the particular institutional contexts of knowledge use and production related to tropical agro-industries in subnational places. Face-to-face interactions allow EMBRAPA scientists to screen for potential sources of knowledge through inter-personal and professional groups and build trust and effort as part of a social production of knowledge with other innovative agents in other places (Urry , Storper and Venables 2004).[8] *Face-to-place* interactions allow EMBRAPA scientists to absorb contextual knowledge such as political-ecological knowledge from natures that surround and embed agricultural experiment stations in Latin America or agro-industrial knowledge that comes from temporary co-location in an agro-industrial systems beyond the walls of the research and development lab of a firm (Latour 1993, Gertler 2010, Latour 2011). Understanding the ways that these relational aspects of mobility serve as a source of a wider spectrum of learning can help to extend existing work that posits more static associations of certain types of knowledge with certain agro-industrial production networks (Morgan and Murdoch 2000, Ponte and Gibbon 2005).

Varying and Comparing Knowledge Use and Production

Over recent years, the mobility of EMBRAPA scientists to Latin America was associated with an increase in the diversity of interactions with subnational locations within Latin America. The number of different subnational locations that EMBRAPA scientists visited in Latin America

[8] This short-term but often episodic mobility of EMBRAPA scientists as a source of learning from more localized forms of knowledge in Latin America should, however, be distinguished from the full spectrum of "buzz" knowledge that c through long-term co-location in urban economies (Storper and Venables 2004).

increased from thirty-five locations in the year 2000 to 122 locations in the year 2010. In the year 2000, the only location that EMBRAPA scientists traveled to in Bolivia was Santa Cruz de la Sierra, which is the largest city in Bolivia as well as the seat of the main agro-industrial region in the eastern *cerrados* region of the country. By the year 2010, EMBRAPA scientists made visits to Riberalta, which borders the Brazilian state of Acre, and La Paz, the national administrative capital in the Andes. This increase of the mobility of EMBRAPA scientists to Latin America associated with ABC included projects between 2007 and 2014 where employees of EMBRAPA acted as *consultants* on three technical cooperation projects that the Brazilian government provided to the Government of Bolivia as part of this government's design of a new public research organization for innovation in agriculture and forests in Bolivia. Prior to the three technical assistance projects associated with the creation of INIAF that formed the basis of research in the current paper, EMBRAPA scientists rarely stepped foot across the border. A total of fourteen different scientists and technicians of EMBRAPA engaged in twenty-one episodes of mobility to Bolivia that were associated with ABC projects during these years. Even in these "peripheral" locations in Bolivia that possess lagging indicators of a base of scientific human capital or innovative outputs, the episodes of mobility of EMBRAPA employees represented only approximately 20% of the relative share of the total episodes of mobility of EMBRAPA scientists to these locations over the period 2000 to 2014. The framework of spatial mobility helps to explain technical assistance projects as one subset of the activities of EMBRAPA scientists as part of a diversity of locations in Latin America.

This locational diversity represents diverse types of knowledge due to the diversity of firms that an EMBRAPA scientists interacts with, following literature that different relations with industry can shape flows of knowledge from firms to public research organizations by providing knowledge on a wider range of technological problems faced by heterogeneous firms, and in different contexts of use (D'Este and Patel 2007). The mobilities data demonstrates that scientists increased the number of meetings with organizations with which it interacted between the year 2000 and the year 2014. This also included an increase in the number of different events, which

proxy a diversity of agents and knowledges, between the year 2000 and the year 2014. Locational diversity in Latin America provide related variances in institutional factors that shape the use and production of agricultural knowledge in ways that allow EMBRAPA scientists to monitor the use and production of agricultural knowledge under different conditions, including, for example, land tenure. Locations in Latin America offer access to a more heterogeneous set of firms and other innovative agents that use and produce knowledge and innovation in a broader set of ways. Locations include a diversity of know-how surrounding locations of genetic diversity. The Andes or the Amazon are recognized as stores of genetic diversity that are important to biotechnology but these are also source of tacit knowledges that may serve as complements to scientific knowledge of biotechnology. Diverse locations represent diverse agro-climatic factors between different agro-ecological zones and environmental context that may serve as a source of knowledge from certain regions that can be used, recombined or adapted in new ways as part of knowledge or innovation in another region.

Relational Platforms in Latin America

The relational aspects of mobility are a potential mechanism of knowledge flows across an array of collaborative arrangements in the production of tropical knowledge. This includes, for example, joint production of knowledge, research through contract or consulting, licensing, joint publications, co-invention, recruitment of scientists and research professionals, joint participation in workshops and other events, joint attendance of international scientific conferences, research visits, staff exchange, joint laboratories. We can begin by developing a basic typology of the relational platforms through which mobile EMBRAPA scientists can learn from people and places in Latin America. EMBRAPA scientists learn through face-to-face contact in *interpersonal knowledge-sharing events* between different arrays of innovative agents from locations in Latin America and Brazil. The mobilities dataset demonstrates that knowledge-sharing events represent

the largest share of episodes of mobility of EMBRAPA scientists to Latin America, with sixty-five per cent of episodes of mobility between 2000 and 2014 consisting of participation in a knowledge-sharing event. These events, such as conference, are venues for EMBRAPA scientists to learn from potentially novel elements of know-how in the moment or in subsequent periods and not merely for the stated role of the dissemination of codified research results of scientific knowledge through the presentation of articles that the bureaucratic categories to Latin America. Face-to-face contact through events allow for interaction with a range of different collections of innovative agents that are based on professional epistemic communities across space that share similar disciplinary training, innovative agents along particular production networks that may integrate innovative agents across disciplinary boundaries but with a shared participation in particular production chains, as well as trade fairs that are focused on firms and private sector actors (Maskell, Bathelt, and Malmberg 2006, Bathelt and Schuldt 2008). This locational diversity can shape diverse types of actors and knowledges even for scientific events and industry fairs (Li 2014). This includes face-to-face contact with innovative practitioner agents from firms in related agro-industries and environmental services that may represent sources of knowhow because industries use events of professional scientific epistemic communities as important meeting points for the exchange of knowledge (Maskell, Bathelt, and Malmberg 2006, 1001). Research on trade fairs and firms suggests that different locations of scientific conferences also bring different types of knowledge together depending on the types of organizations, knowledge bases, firms and regional economies in which the event is located (Li 2014). The mobilities data suggests that approximately forty per cent of knowledge-sharing events are local or regional in nature and thus insert EMBRAPA scientists and their home regions into situated pools of knowledge in particular places in Latin America that reflect differences based on the places where these are conducted that may provide opportunities to learn from people and places from Latin America that may be differentiated from a circuit of knowledge of people from Latin America that travel less to meetings in places such as the United States, Europe or Brazil.

EMBRAPA scientists engage in face-to-face learning through interactions with people in Latin America as part of *projects* seek to achieve a particular goal in a certain period. The consulting projects of EMBRAPA scientists represent temporary relations associated with projects. These usually bring together a more limited number of innovative agents as part of collaborations between individual scientists as well as through inter-organizational agreements and contracts. Face-to-face learning through mobility can be important at particular moments in the development of projects, and perhaps especially so in the initial stages of formation of projects (Torre 2008). Although these are formal agreements, one of the implicit goals may also be the exchange of know-how and tacit knowledge through spillovers of knowledge that are developed through the course of the project. The mobilities dataset demonstrates that 20% of episodes of mobility were conducted as part of a project. The face-to-face learning through projects may also be distinguished in terms of the forms of coordination that structures the project, including paid consultancies as well as projects that do not involve money. Face-to-face learning includes the episodes of mobility that EMBRAPA scientists conduct as part of ABC projects as well as, for example, projects between scientists and others in Latin America. These projects may establish inter-personal trust that allows for spillovers of more tacit knowledge between participants and may also bring EMBRAPA scientists into contact with people and places outside of the formal members or goals of the project.

Individual EMBRAPA scientists may also learn through face-to-face contact by participating as representatives in meetings of *networks* for ongoing exchanges of knowledge. These may serve as venues for learning through know-how because these may bring together a similar group of people over an indeterminate amount of time in ways that establish trust. This includes inter-organizational networks that bring together certain types of organizations as part of projects such as Mercosul, Procitropicos and Procisul. This includes the maintenance of the inter-organizational agreements such as those of scientific and technical agreements between actors. This also may include networks of non-state researchers and here we can include the existence of environmental networks that organize actors in different ways. EMBRAPA scientists engage in

face-to-place learning through *visits* to places in Latin America. Approximately fifteen per cent of episodes of mobility included visits to places in Latin America as part of the planned itinerary of activities. Approximately twelve per cent of mobility episodes included visits specifically to places themselves: regions, fields, organizational laboratories that provide practical experiences present. This offers opportunities for learning by "being there" in a particular region or regions, whether this was an open-air laboratory or visiting organizational facilities such as laboratories. This included visits to places as part of knowledge -sharing events in a particular region. These may present a relatively unstructured opportunity to interact with a wider range of actors that possess know-how, and to learn from places and landscapes in ways that are complementary to exchanges of know-why exchanged in scientific conferences.

Learning Beyond One-Way Transfers

This framework of a broader spectrum of learning is developed through examples from cases of mobility of EMBRAPA scientists as consultants for technical assistance projects provided by the Brazilian government to the Bolivian public sector. Since regions in Bolivia sit at the low end of the Latin American range on standard indicators of human capital and research and development infrastructure, these examples serve to illustrate the utility of a broader analytical lens of knowledge from otherwise unexpected sites and situations. This section suggests that face-to-face and face-to-place contact in a broader variety of locations within Latin America provides opportunities for EMBRAPA scientists to absorb knowledge comprising know-how in the course of delivering planned one-way transfers of knowledge to other locations. This approach re-directs attention to the quality of knowledge exchanges facilitated by mobility and away from the transactional delivery of knowledge for planned objectives.

These cases suggest that broader facets of learning developed alongside planned transfers of knowledge from EMBRAPA to the Bolivian Ministry of Rural Development Agriculture

and the Environment and a new National Institute of Agricultural and Forestry Innovation (INIAF). a new public research institute in Bolivia. Beginning in 2007, EMBRAPA scientists participated as consultants in three projects on the general organization of this institute as well as particular areas of conservation of genetic resources and the production of seed technologies.[9] Evidence from review of project documents and interviews suggest that a significant component of such activities consisted of brief interactions and codified knowledge on the organization of INIAF. Evidence suggests an often perfunctory and codified nature to the knowledge that EMBRAPA scientists provided to agents in Bolivia. For example, when pressed to distinguish the knowledge and services that he was providing to INIAF, one scientist stated that there was little of novelty and that scientists from organizations other than EMBRAPA could have provided similar to counterparts from Bolivia. This does not preclude this utility of basic knowledge at initial points of project design in Bolivia but it raises questions on the significance of these activities for full-time research scientists from EMBRAPA.

Searching for Tacit Dimensions of Knowledge and Comparisons

This study, suggests however, that these interactions also express sources of partially tacit information, for instance through the comparison of differences in institutions and know-how between varied locations within Bolivia versus those within Brazil. Interviews with scientists in EMBRAPA with experience with technical assistance projects in Latin America suggest that learning is an objective of EMBRAPA scientists and that there are attempts to align by EMBRAPA with an organizational commitment to demand-driven transfers of knowledge to requesting

[9] Between 2007 and 2009, EMBRAPA scientists were consultants to the Bolivian Ministry of Rural Development, Agriculture and the Environment with the objective to “provide Bolivia” with recommendations on the organizational design of INIAF. A subsequent project between 2009 and 2011 called for EMBRAPA scientists to advise the leaders and staff of the recently-created INIAF on the organization of INIAF regarding the production of seeds. A third project from 2009 until 2011 called for EMBRAPA scientists would provide knowledge to INIAF employees on the conservation of genetic resources.

partners in Latin America and Africa. There was, as one scientist noted, an initial interest for consulting activities for government technical assistance projects in Latin America to function in a fashion more akin to collaborations with more traditional scientific partners in Latin America, although this was also inhibited by inter-organizational distance in research capacity and infrastructure. Comments from two other scientists on more recent consulting activities in Latin America indicate that there is an ongoing discussion among scientists as to how to include learning among EMBRAPA scientists within the learning from such projects. As one senior scientist noted, scientists document such knowledge. At the same time, the codification of knowledge in project reports did not necessarily point in a clear direction. The broader breadth of knowledge within the heads of EMBRAPA scientists in comparison to project documents points towards the need for frameworks to consider more tacit dimensions of learning by and between EMBRAPA scientists beyond organizational objectives.

Institutional arrangements of innovation in agro-industries is one area that examples point to in which knowledge includes more tacit elements beyond organizational blueprints. Interview with the scientist discussed in the prior section on organizational transfers also discussed institutional arrangements of organizational plans and categories that influenced the translation of knowledge across different production systems associated with different size classes of producers. Conversations veered into comparisons of the implications of transferring certain organizational models from Brazil to Bolivia when the regional systems of production were different, and in which the polities were different. This scientist was able to contextualize the current project of organizational restructuring of INIAF by drawing from historical knowledge and situational knowledge from previous projects of institutional restructuring in Bolivia. We can think of as a tacit experience with institutional factors shaping the context of agricultural innovation in this project. Differences in institutional characteristics that shape production systems, including land tenure, political institutions and laws on forests in places such as Bolivia therefore represent potential sources of learning on the performance of similar technologies in different institutional contexts in which these are used.

Examples from Bolivia also indicate that tacit dimensions of crop know from socio-natures in localized area of genetic diversity and biodiversity in the Andres or Amazon possess potential sources of localized knowledge of interest to EMBRAPA scientists and regions in Brazil. Interviews with EMBRAPA scientists suggest that there is an interest in learning from genetic knowledge in locations in Bolivia and the difficulty in formalizing international transfers of germplasm suggest that these tacit dimension may complement structured scientific research at home in Brazil. This suggest that projects on genetic resources and seeds in which knowledge on crops such as potatoes or quinoa is embedded in indigenous knowledge systems may be sources of complementary knowledge on potentially useful traits of particular varieties of seeds from experience with the use of different varieties in particular regions or institutional contexts. Visits to in-situ sites of genetic knowledge by EMBRAPA scientists in Latin America as part of these projects are thus a potential source of more unstructured face-to-place and face-to-face contact that may produce potentially novel sources of knowledge as know-how for use at home in Brazil. These examples remain suggestive and require further confirmation, but as international transfers of germplasm become more restricted, these tacit dimensions may become more important and are areas for future research.

These examples of everyday aspects of tacit knowledge in a limited number of cases in Bolivia help to illustrate the broader dimensions and direction of knowledge exchanges. These lay the groundwork for a re-interpretation of such activities that can be confirmed through targeted research into the future. The suggestion of tacit aspects of knowledge of EMBRAPA scientists as part of INIAF activities does not necessarily mean that these served as a source of learning that was novel to regions in Brazil but it does illustrate the ways that participation in unexpected sites of learning such as projects of technical cooperation can serve as an informal entrée to institutional factors and know-how that complements processes of scientific development in tropical agro-industries and related land uses. These examples bring into the light the ways that locations in the periphery serve as examples of potentially interesting elements from a broader

spectrum of knowledge that EMBRAPA scientists or other actors in home regions of Brazil that may be able to recombined with processes of innovation that are conducted closer to home.

PERIPHERAL PATHWAYS TO SPILL-INS: EARLY, EXOTIC, ENVIRONMENTAL AND INSTITUTIONAL

This section illustrates the peripheral causal pathways through which mobility shapes knowledge production and innovation by examining the composition of mobile relations in knowledge products and patents produced through EMBRAPA scientists and innovative people and places in the wider Americas region.[10] The findings – in aggregate – demonstrate a small but increasing share of knowledge flows from Latin America to EMBRAPA via indicators of citations from Latin America to papers of EMBRAPA but that formal processes of innovation are localized in home regions in Brazil. Mobility should be understood as a conditional, rather than an automatic, contributor to the production of knowledge. The initial findings from this exploration suggest the positive effects of diversity are more likely in formative moments and less structured fields and productions networks. The exploration of the case of Bolivia suggests that this relates to institutions, environments and exotic crops. This section uses collaborations and citations of the production of patents and knowledge products in order to explore the relational or spatial proximities that mediate extra-local learning (knowledge spillovers). This section suggests that

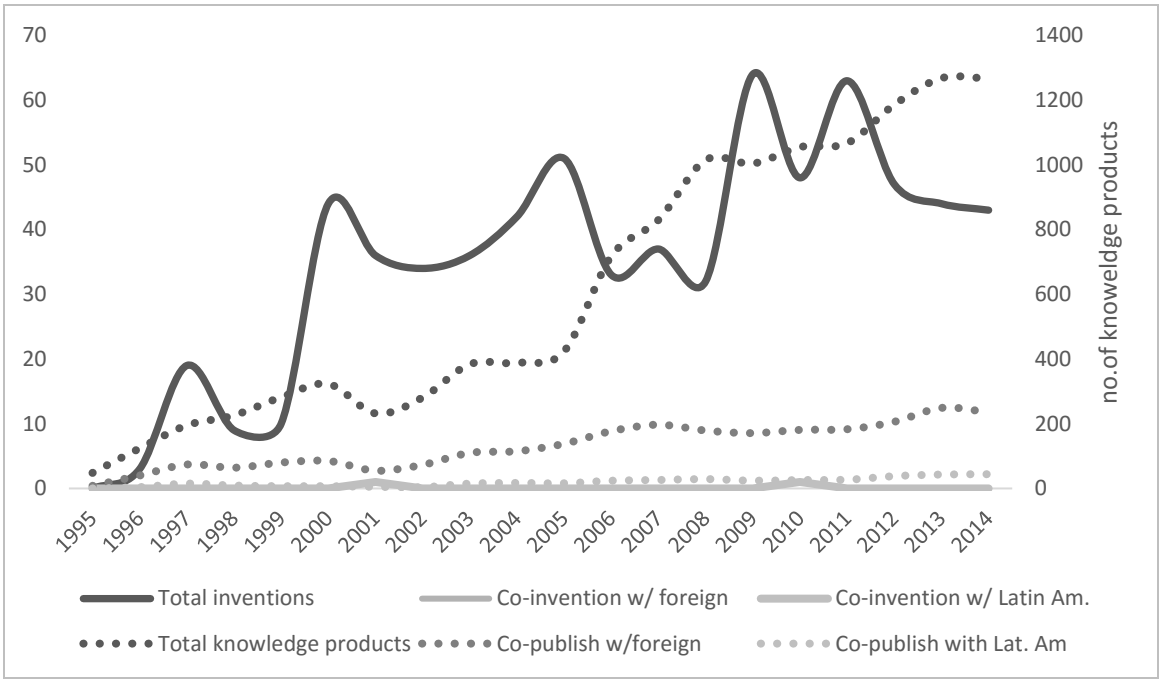
[10] This paper examines papers and patents as indicators of intermediate outcomes of knowledge production as "pathways of innovation" (Azoulay, Graff Zivin, and Sampat 2011, Nelson et al. 2014). The practice in the literature of using patent citations from the United States and Europe as an indicator of knowledge spillovers is not possible for patents in Brazil, for which citations are not a standardized convention in patent applications. Patents are also likely to be a less reliable indicator of invention as part of innovation processes in the case of Brazil and Latin America because institutional differences in intellectual property rights in these places are likely to lead innovators to protect a more limited share of knowledge through formal patent processes in comparison to the United States and Europe.

flows of know-how to EMBRAPA scientists and collaborators may be more important in less structured areas of inquiry on agro-industries and environments and more spatially-proximate knowledges on less structured areas of scientific inquiry on agro-industries and environments. This also suggests ways forward for an identification strategy of knowledge production and citations that can be used to examine possible sources of spillovers to EMBRAPA scientists.

Proximities Mediate Spill-ins

This framework integrates the geography of learning from Latin America into more general geographical explanations of agro-innovation by EMBRAPA scientists by conceptualizing mobile relations as a me framework argues that occurs over distance but that EMBRAPA scientists localize more formal processes of innovation in home regions of Brazil. This paper puts extra-local learning from Latin America into context by arguing that this is complementary dimension of local endogenous processes of innovation by EMBRAPA scientists in home regions in Brazil. This framework suggests that learning and innovation are possible over distance but that there is a distance decay of knowledge flows of know how over distance that can only sometimes be mediated by other sorts of proximities. also subject to different social factors and geographical conditions. This is an alternate framework of the more limited agronomic models that see knowledge as ubiquitous. This responds to the work of proximities as mediators of distance (Morgan and Murdoch 2000, Boschma 2005). Figure 3-4 presents data that demonstrates that cross-border knowledge products and inventions both represent a small share of the total production by EMBRAPA scientists.

Figure 3-4 Spatial Proximity in Social Production of Knowledge and Inventions by EMBRAPA Scientists, 1995-2014



Sources: (INPI , Elsevier 2016, SNPC 2016, WIPO 2016)

This paper suggests that Latin America serves as a source of bits of knowledge to scientists from EMBRAPA but that as processes of innovation become more formalized and complex that this is more localized in home regions in Brazil. These results are also used to argue that space play a role in the attenuation of flows of know-how across space and provides an alternative to existing literature in agricultural innovation and in the agronomic models that do not conceptualize space as an attenuating factor in knowledge flows. Only two out of a total 776 registered inventions held by EMBRAPA on which there is data on the inventors were produced through collaborations between an EMBRAPA scientists and at least one co-inventor in Latin America and indicators of the production of knowledge in the second chart demonstrate that this is also the case with respect to relations of knowledge production. This demonstrates that only 430 out of 8,000 articles produced by EMBRAPA involved a collaboration with an extra-local actor from Latin America.

The temporality of the mobility of EMBRAPA scientists to Latin America should also be understood as a factor that mediates the effects of mobility on learning. The results from the mobilities dataset demonstrates that mobility to Latin America is almost entirely of a short-term nature, in contrast to mobility to the United States and Europe where mobility includes longer term episodes for purposes of graduate education and post-doctoral exchanges. The average length per episode of mobility of EMBRAPA scientists to Latin America was approximately one week, with ninety-nine per cent of mobility episodes were for a duration of less than one month.[11] Ninety-nine per cent of mobility episodes fit the category of brief "temporary" knowledge interactions that many suggest will inhibit the sorts of embeddedness and trust that permit more richer tacit flows of knowledge (Edler, Fier, and Grimpe 2011).The mobility of EMBRAPA employees to Latin America is therefore best understood in terms of debates in the literature concerning limited duration scientific mobility as a factor in the production of knowledge and innovation, for example, as a type of brief temporary mobility that shapes knowledge flows in similar ways to trade fairs and scientific conferences (Torre 2008). The EMBRAPA mobilities data demonstrates that the average length per episode of mobility of EMBRAPA These visits should be understood as brief visits in the category of the literature on the role of mobility to facilitate face-to-face contact and co-location in scientific conventions, trade fairs, and projects as part of innovation (Torre 2008).

Mobile Patent Pathways: Spill-ins Beyond Collaborations on "Core" Patented Inventions

This section examined pathways of examining basic data on the relational and spatial composition of co-inventor relationships as part of the production of patents. The first of only two patent cases that involved a scientist from EMRAPA and at least one author person from Latin America was from collaborations of researchers from Campo Grande in the state of Mato Grosso

[11] The figure of seven days derives from an average of eight less one day of travel time.

do Sul in the center-west region of Brazil where the unit of EMBRAPA that focuses on beef cattle, in collaboration with scientists in a traditional center of multilateral science, the International Center on Tropical Agriculture (CIAT) in Cali, Colombia in the year 2001 for genetic inventions in *brachiaria*, the tropical forage grass that was one of the signature areas of innovation by EMBRAPA in the expansion of agro-industrial cattle production in the center-west region of Brazil in previous decades. The lack of data prior to the year 2000 makes it difficult to assess the role of mobility but evidence suggests that mobility was part of a long-term collaboration between agents that began more informally in the mid-1980s, later was converted into an inter-organizational effort in 1991 and then was formalized as a scientific collaboration with funding in 1994 (Miles, Maass, and do Valle 1996, vii-viii). In many ways, this represents a central and relatively structured research project of EMBRAPA scientists. The second patent case from 2010 was for the development of a composition to control insect infestation in the primary production of a number of commodity crops such as coffee and cotton involved EMBRAPA scientists from Brasilia, Brazil, where the largest organizationally-decentralized unit of EMBRAPA focuses on genetic resources and biotechnology is based in close proximity to the administrate headquarters of EMBRAPA in the same city. This effort comprised collaborating agents from academic organizations in close proximity in the city of Brasilia. This included researchers from the public University of Brasilia in addition to scientists from more distant locations in Latin America: in Mexico City where the National Polytechnic Institute is located, as well as San Jose, Costa Rica where the University of Costa Rica is located. There is risk in inferring too much from the single case but this data suggests that these fit the description of formalized stable agreements between centers across space that bridge the challenges of space through formalized inter-organizational collaborations. The role of mobility plays a role in these, as the data suggests that it also does in Labex. Despite the limited results of cross-border collaborations, these are the result of relatively new processes since the turn of the century, with the first patent in 2001 and two patents more recently in 2010 and 2015, and may be increasing moderately over recent years. These may underestimate

innovations that do not rise to the level of patents, these may be due to the time frame. These occurred across space between locations and organizations with knowledge.

The analysis of the role of the patent in terms of a patent-paper pair suggests the role of elements of learning from broader set of actors in Latin America suggest as well as a possible methodological approach to studying these in the absence of patent citations. By tracing a paper that was produced by the same authors and on the same topic as the 2010 patent during the same time frame we can citations as knowledge spillovers based on the knowledge in the article that is related to the 2010 patent. This approach demonstrates a wider range of individuals from locations in Latin America that EMBRAPA scientists visited but whom were not formal co-inventors contributed knowledge as part of the paper-patent pair. This evidence is does not allow us to examine how or when or through what means this was obtained and certainly part of these citations are likely to be through codified means that were not shaped by mobility but we can follow the literature on patent citations and suggest that citations from particular locations represent overflows of knowledge associated with mobility to these locations include spillovers of knowledge that included tacit elements, for example through direct mechanisms of contact with people or places and or indirectly through the spillover of knowledge from a direct collaborator about the related research of other people or places in the region.

Spillovers of Knowledge for Learning at Home

The mobilities dataset demonstrates that eighteen per cent of the total episodes of mobility (605 out of 3424) were conducted by an individual that later produced knowledge with at least one other person from Latin America. These episodes represent one hundred and eighty different mobile scientists from EMBRAPA associated with knowledge outcomes. New data of the stock of invention of EMBRAPA at the level of the individual scientist permits identification of EMBRAPA movers to Latin America that had practical experience in innovation prior to engaging in mobility to

Latin America. The data on the co-scholar works finds that fifty-five different movers conducted 100 episodes of mobility to these four countries the Andes-Amazon plus Paraguay who later co-produced knowledge with someone from Latin America.

Exotics and Non-Traditional Production Networks

This paper uses this data to suggest that spill-ins from locations from Latin America are more likely to be of most importance in less structured areas of knowledge and along production networks that area less consolidated. In Bolivia, this included, for example, stevia, forests, Brazil nut and the potential for quinoa. We can think of genetic resources in less commercial products, environmental aspects, new technologies in agricultures, institutional aspects of innovation for knowledge. This suggests that the most important areas in which these processes of knowledge search may shape processes of innovation are in 'exotics' and less common products. This evidence that suggests spill-ins of knowledge between cross-border regions that may flow below the radar are also suggested by seed cultivars that are known to be part of cross-border, inter-regional exchanges between scientists and organizations in the Brazilian state of Mato Grosso and the Bolivian state of Santa Cruz, for example, of that between regional institutions in Brazil and regional organizations in Bolivia such as the relationship of Fundação Santa Cruz in relationship with Fundação Mato Grosso in the past or social relationships between EMBRAPA and the sub-national research organization of CIAT in the city of Santa Cruz.[12] Collaborations that included at least one EMBRAPA scientist and one collaborator from Bolivia produced 26 knowledge products. This beginning in 1998, social learning processes. The affiliations of researchers in Bolivia during this period raise questions regarding the role of state-to-state relationships in the role of knowledge production. In Bolivia, these are recent processes of

[12] This refers to the subnational organization and should not be confused with the CIAT of the CGIAR

knowledge production. 24 of 25 knowledge products that have been produced across borders happened since the year 2003, with the remaining product in 1998. These are recent processes that appear to be increasing, albeit from a very limited level and only gradually.

These findings suggest that spill-ins of knowledge occur in non-traditional and exotic production networks rather than more standardized and capitalized industrial agricultures associated with major crops of the type that figure into agronomic spillover models. One of the examples where a prior example of article is related to current patterns of mobility is in the case of non-timber forest products. Brazil nuts. Interestingly, this is one of the few areas where industries in Bolivia upgraded in ways that those in Brazil did not, and so may suggest a potential area for the flow of knowledge (Coslovsky 2014). This, though, also suggests the importance of proximity. There are also suggestions that the tropicalization[13] of niche quinoa exotics in Brazil may be a source of spill-ins. This project on quinoa expresses the potential for innovation projects from across different ecological and institutional environments that are developed through the incipient relations between EMRAPA and INIAF. The role of quinoa in the savannahs of Brazil (Spehar, Barros Santos, and Jacobsen , Spehar et al.). Tropical quinoa is an example of the sort of project that this represents. This suggests that these processes may be less interesting as knowledge search in areas of standardized technologies and production systems such as soybeans but be more interesting in other combinations, for example of the tropicalization of quinoa, or the use of new technologies. There is evidence of scientists from EMBRAPA interested in genetic knowledges and other resources from places such as Bolivia (Diniz 2013).

This evidence considers factors other than the agro-climatic factors of spillover models in major commodity crops are important parts of explanation of the geography of knowledge flows. This includes institutions, relations and politics as factors that help to explain the geography of relations between EMBRAPA researchers and locations in Latin America. One example is the

[13] This refers to the adaptation, translation or recombination of crops from a non-tropical region to a region in the tropics

contrast in the relations of EMBRAPA scientists in the eastern regions of both Bolivia and Paraguay are in the *cerrados* biome that models of spillovers forecast to shape spillovers. This contrasts with Paraguay, where only one work could be classified as environmental knowledge. Also, although Paraguay and Bolivia eastern regions share some similarities as areas of soybean production, no works of collaboration were focused on soybeans, whereas 6 of 17, or 30%, in Paraguay were focused on these areas. Another companion case we can consider is Ecuador, where researchers also participated in the Amazon networks with researchers from EMBRAPA. There were limited but slightly more other works in other areas between Brazil and Ecuador.

Beyond State-to-State: Diverse Collaborators

The evidence on the organizational affiliation of researchers in Bolivia that collaborated with EMBRAPA represented thirteen different organizations. This did not include scientists from INIAF or other public organizations of agricultural innovations but this did include nonprofit organizations, producer associations, museums and scientific organizations, and collaborative research programs between organizations, including associated with organizations in Europe or the United States. In the case of Bolivia, outcomes of knowledge production between Brazil and Latin America were in many cases, broad networks arranged at more global sales scales that were concerned with forests, for example in the Amazon, rather than agro-industrial frontiers. This variety of inter-regional connections between places is also a finding of evidence in the broader Latin America region. Paraguay, for example, next door to Bolivia and a similar comparison case, presents a greater degree of research for example, on soybeans in comparison to Bolivia.

These findings suggest that these flows of knowledge comprise environmental knowledges related to tropical forests through networks of researchers. The knowledge ties between EMBRAPA scientists and researchers in Bolivia are strongly specialized in knowledge about tropical forests. 21 of 25 knowledge products, or 84% of knowledge products, with Bolivia concerned tropical forests, particularly in the Amazon region. The includes conservation biology on forests, as well as forests for non-timber forest products, such as the Tropical Managed Forests Observatory, an international network that merges information from experimental sites across as well as RAINFOR and PPBio networks on logged forests. For example, this includes a network of over one hundred scientists in the Amazon and specialists globally that conduct research on the Amazon. The Amazon Forest Inventory Network is a long-term, international collaboration to understand the dynamics of Amazon ecosystems that jointly developed a framework for systematic monitoring of the forests from the ground-up, and which centers on permanent forest plots that track the behavior of individual trees and species, and includes extensive collection of soil and plant biogeochemical data, as well as more intensive, high frequency monitoring of carbon cycle processes at key sites. This included a Brazilian networked program for research in biodiversity. that was created in 2004 in order to increase and decentralize the scientific study of biodiversity in Brazil as well as to integrate activities in different locations.

CONCLUSION

These findings and framework contribute to a more robust explanation of the geography of innovation in tropical agro-industries and related environmental services of EMBRAPA scientists in

tropical agricultures. This contributes the first empirical evidence of mobilities as well as the first multi-sited interview evidence of the locations and logics of scientific consulting project in Bolivia and Latin America more generally. These empirics provide a base of evidence that moves beyond the domestic versus foreign dichotomies as well as inter-national approaches to the geography of knowledge production by EMBRAPA scientists. This data demonstrates that 35% of mobility was to Latin America and argues that this is part of knowledge production. This paper argues that beginning from a framework of mobility serves to integrate cross-border activities such as travel associated with technical assistance projects into a more general framework of the global geography of knowledge production of EMBRAPA scientists.

The framework of mobility contributes to the literature by incorporating the particularities of these locations into a more general explanation of mobility of EMBRAPA scientists in the production of knowledge and innovation rather than cleaving these activities off into a narrow separate debate over foreign aid (Lorentzen 2009). The empirical findings and conceptual framework demonstrate the importance of integrating diversity as a dimension of knowledge be introduced as a potential contribution rather than inhibiting factor that explains the advantages of other locations in Latin America rather than merely as a friction or as a diversion from core activities. This paper suggests the importance of not only de-constructing narrative parallels based on similarity but also of conceptualizing place-based sources of variation in knowledge production that may facilitate knowledge flows. The findings and framework the conceptualizes scientific mobility as a source of spillovers of knowledge that includes more tacit forms of know- how broadens the existing interpretation of the mobility of EMBRAPA scientists in terms of multi-dimensional mechanisms and contributes to the existing literature that has primarily interpreted the activities of EMBRAPA scientists in terms of the acquisition of formal education in scientific knowledge from advanced centers of science in the United States and Europe. This framework on diversity provides a more finely-grained approach to understanding place-based differences within these broad biomes of the *cerrados* and the Amazon – both in Latin America but also potentially

more widely in Africa - that are not captured through approaches that elide differences in “south-to-south” interactions or forecast spillovers on the basis of agro-climatic similarity.

This also incorporates a focus on a wider set of production networks and fields of environmental knowledge and institutional knowledge in tropical agro-industries and to environmental sectors at particular formative moments as well as to integrate knowledge of natures into frameworks of spillovers and broader processes of institutional innovations. This contributes to understanding of the role of environmental factors in technological change (Leach et al. 2012).The findings and framework of this study that seek to emphasize the relational aspect of mobilities and diversities also contribute to literature on the study of Labex by suggesting that face-to-face contact adds particular forms of learning that are differentiated from online components of knowledge flows and learning. If this seems peripheral, so too were soybeans decades ago when they grew from an unexpected exotic that grew into a core agro-industry that expanded across Brazil. These results produced a framework for statistical analysis at the global scale on the effects of mobility on knowledge production by scientists from Brazil in ways that extend beyond a small set of activities associated with the foreign virtual laboratories. Subsequent research will examine these processes in a more disaggregated manner at the level of individual researchers or researchers.

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Chapter Four. Beyond the Fence of the Brazilian Farm: New Branch-Level Evidence on Brazil-based Agro-Industrial Firms in Latin America

INTRODUCTION

Analysts forecast that nearly half of the largest firms in the world will be based outside of the United States and Europe in locations within so-called emerging economies such as Brazil, China and India by the year 2025 (Dobbs et al. 2013).[1] This unprecedented but still poorly-understood shift comprises new geographies of knowledge flows and other production relations beyond trade that have implications for economic organization and environmental changes not only in the subnational regions within these countries, which were home to only five per cent of such firms in the year 2000, but also in locations at global scales.[2] The poorly-understood geographies of these 'emerging multinationals' include large firms from Brazil in agro-industrial systems that extend to associated sectors both upstream and downstream of the traditional focus on primary production on the farm. Over the last decade, there are poorly-understood cases of multi-locational firms from Brazil such as grains producers that attempted to obtain six million hectares of land in the savannahs of Mozambique or livestock processors that acquired firms across Latin America. The main bottleneck to more robust explanations of these global activities of

[1] This paper uses the term 'emerging' as a shorthand to denote the *recent* and still *indeterminate* nature of heterogeneous large-scale economic processes outside of the so-called triad of North America, Western Europe and Japan. For the limits of our existing categories, see e.g. Armijo (2007) or, from a different angle Crescenzi, Rodriguez-Pose, and Storper (2012).

[2] The projected share for the year 2025 (45%) refers to firms with at least US$ one billion in annual revenue.

agro-industrial groups from Brazil is the lack of aggregate empirics at more granular levels of locations below the nation-state and of organization of activities other than the conglomerate.

This paper constructs new insights on the dynamics of agro-industrial restructuring associated with firms from emerging economies by constructing and examining new evidence on the scope, location and organization of the largest agro-industrial firms from Brazil that have branches in Latin America. Existing explanations largely approach the growth of large firms from Brazil as export-oriented farmers from the tropical breadbasket of the Brazilian farm. However, new cases of production by multi-locational firms from Brazil that extend beyond the borders of the nation-state and over the fences of the farm require updated explanations of multinational agro-industrial firms based in Brazil and other emerging economies. These cases challenge paradigmatic 'north-to-south' explanations in which developing country agribusinesses were outcomes of agro-industrial restructuring by agri-food multinational firms based in the United States and Europe in the 1980s and 1990s (Friedmann 1991, Bonanno et al. 1994, Goodman and Watts 1997, Rama 2004). This paper approaches the current era by departing from the question that researchers asked of Brazil and other 'new agricultural countries' in the 1990s: are agro-industrial firms from Brazil genuinely global and what are the production relations and institutional factors that shape these chains across space and sectors (Rosset, Rice, and Watts 1999, 72)?

There are extensive empirics on agricultural production within Brazil but analysts have only recently begun to investigate new processes in which agro-industrial firms from Brazil also organize production on and beyond the farm at wider regional and global scales. Site-based case studies of grains production in the tropical savannahs of Mozambique or firm-based analyses of Brazilian livestock processers in Latin America provide important insights into these recent processes but we also need aggregate empirics in order to understand the broader implications of such cases (Galeano 2012b, Cabral et al. 2013, Degen and Wong 2013). Existing explanations based on capital flows data from national accounts are limited by the high level of geographic and sectoral aggregation of this type of evidence as well as the imperfect proxy that it provides for production (UNCTAD 2010). Leading analysts argue that firm-level evidence offers a more

detailed view on multinational agro-industrial firms but the available datasets do not cover the period of spatial restructuring by agro-industrial firms from Brazil and other emerging economies over the last decade (Rama and Martinez 2013). This paper addresses this gap in the literature by compiling the first dataset of the scope, location and basic organization of the branch establishments of subsidiary firms in Latin America that were controlled by large agro-industrial groups from Brazil in the year 2013.

This paper uses this new evidence to argue that agro-industrial production by firms from Brazil in Latin America is an uneven and multi-scalar process by a small number of firms that specialize in downstream sectors and livestock and grains commodity network rather than a Brazilian agri-food globalization across Latin America. This paper proceeds in the following manner. The first section locates recent cases of agro-industrial firms from Brazil in a framework of global production networks and considers insights from existing literature that seeks to explain the restructuring of agro-industrial production associated with the rise of agri-food firms from the emerging economies over the last decade. The next section examines the scope, the location and the basic organization of agro-industrial production by firms from Brazil in Latin America and argues that these activities are uneven processes that cluster in the Southern Cone and centers on red meats production chains and sectors downstream from primary production on the farm. The fourth section discusses the implications of these patterns for explanations of large firms from Brazil as causes of agro-industrial and land-based change as well as the ways that these new cases may diverge from existing explanations of restructuring based on firms from other locations and in previous eras.

EXPLAINING EMERGING MULTINATIONALS AND DIVERGING AGRO-INDUSTRIES

The question of the spatial restructuring of agro-industrial firms from Brazil over the last decade is located in classic debates over the globalization of agri-food industries associated with multinational firms in the 1990s (Bonanno et al. 1994, McMichael 1994, Goodman and Watts 1997). These explanations revolved around and continue to be synonymous with the globalizing apparatuses of multinational agro-industrial firms from the United States and Europe: meat processors such as Tyson Foods, the input giant of Monsanto and the so-called 'ABCD' grains traders.[3] However, do these theories fully explain newly ascendant agro-industrial firms from the emerging economies such as the meat processor JBS from Brazil, the input company Rainbow Chemicals from China or the sugar agribusiness Illovo from South Africa that are also, to use the popular terminology, 'going global' (Hall 2012)? These are new entrants to an unsettled debate from the 1990s between analysts that viewed the globalization of agro-industries as a process of global convergence and others that argued that global agri-food systems were comprised of a range of processes that continued to produce differences across space and commodity chains (Bonanno et al. 1994, Goodman and Watts 1997). The present research that examines agro-industrial firms from Brazil on the ground in Latin America is an important way to begin unpack the implications of these new cases for our explanations of the ways that agro-industrial restructuring processes associated with multinational firms may differ across space and time.

In the 1990s, researchers of global agri-food questions examined the growth of export-oriented farmers and high-value foods from Brazil and other 'new-agricultural countries' that became the 'emerging economies' of today.[4] However, in the previous era the scale of production was limited to the borders of the nation-state and firms in global agri-food systems were effects of

[3] ABCD is an acronym for the four large grains traders, ADM, Bunge, Cargill and Louis Dreyfuss.

[4] Analysts derived the term 'new agricultural countries' (NACs) from the term 'newly-industrializing countries' (NICs) in order to describe new forms of agricultural growth in developing economies.

restructuring from dominant firms from the North, for example through the offshoring of primary production by firms based in the United States or Europe (Friedmann 1991, 1993, Rosset, Rice, and Watts 1999). These existing explanations cannot fully explain some current cases of large firms from Brazil and the emerging economies that organize production at global scales and which possess agency to shape changes that reverberate through global production networks and associated processes of land-based change. The exception was the prescient research by analysts of firms from Southeast Asia such as the CP Group from Thailand that this paper discusses below (Burch 1996, Goss, Burch, and Rickson 2000, Burch and Goss 2005).[5] The present research on firms from Brazil in Latin America provides insights into change over time in firms from Brazil but also the ways that transnational agro-industrial firms differ across different locations.

This paper uses a global production networks (GPN) framework to conceptualize firms from Brazil as multi-locational and polycentric organizations that are located in networks of relations with other agro-industrial firms as well as broader segments of society across multiple territories of production (Dicken 2001, Coe, Dicken, and Hess 2008). This approach acknowledges the insights of agrarian political economy on the particularities of the globalization of agri-food systems but adopts a wider interpretive framework in order to locate this research on agro-industrial – and not only agricultural - firms in wider explanations of industrial change beyond the farm. This framework that couples explanations of firms with a richer view of the multiple territorial processes in the locations across which production is organized has advantages over theories in business economics and management that abstract multinational organizations from broader industrial and societal influences (Fleury and Leme Fleury 2009). The geographical framework of this approach also draws from a broader analytical toolbox through which to view the inherently

[5] Cases from Thailand and Indonesia as well as Mexico or Argentina highlight the importance of extending our analytical frames beyond the set of the 'BRICS' of Brazil, Russia, India and China (Casanova et al. 2009).

spatial processes of multi-locational restructuring that frameworks in other disciplines often treat as dichotomous processes of domestic and foreign production at the level of the nation-state.

What are the existing explanations of agro-industrial firms from Brazil and the ways that these differ from firms in other places? This section interrogates the existing literature on the particular sources of divergence of firms across different locations.[6] Analysts from business economics and management are conducting research on the distinctive nature of *intra-firm organization* in emerging multinational firms beyond agro-industry. This includes aspects such as the particularities of family-ownership, the economies of scope, or the intra-firm financial flows that are prevalent in firms from emerging economies (Cazurra and Ramamurti 2014). These insights are not specific to the agro-industrial sector but they suggest lines of enquiry that may link to analysis of case studies of livestock firms from Brazil (Dalla Costa 2009, Gabardo da Camara, Amâncio Vieira, and Sereia 2011, Pereira Pelláez 2012). Other analysts of agribusiness also suggest that firms from emerging economies organize and locate innovation processes in particular ways due to their tendency to compete at a greater distance from innovation frontiers in their industry (Rama and Martinez 2013).

There are also potential differences at the level of the *inter-firm relations* of agro-industrial firms in production networks. Some analysts claim that agribusiness from emerging economies exhibit a greater internalization of production tasks within the firm in comparison to firms from the United States and Europe that organize production through more external networked relationships (Goss, Burch, and Rickson 2000, Burch and Goss 2005, Rama and Martinez 2013). Analysts argue that firms from Southeast Asia integrated downstream retail sectors with processing sectors and input suppliers in distinctive ways (Burch and Goss 2005). However, other analysts suggest that the opposite may be true given the importance of more networked forms of contract farming and outgrower schemes among firms from emerging economies (Burch and Rickson 2007, Hall

[6] A complete review of the general determinants of the location and organization of agro-industries in the context of globalization is outside of the scope of the current paper. See, for example, Reardon and Barrett (2000).

2012). The production networks in which firms from emerging economies participate may also differ to the extent that these are destined for final markets in China and India since some analysts claim that these final markets will cause to a downgrading of production standards (Kaplinsky and Farooki 2010).

Territories of production are also a source of institutional differences in agro-industrial firms from emerging economies. The 'home environment' as well as territories of production of subsidiary firms of multinational firms from emerging economies are factors that may influence firms from emerging economies in particular ways (Burch and Goss 2005, 257, Cuervo-Cazurra and Genc 2008). In this line of research, the multiple territories of production of firms from Brazil at global scales are potential factors that influence broader aspect of firms and associated processes of restructuring (Alemu and Scoones 2013, Chichava et al. 2013, Craviotti 2016). The roles of state regulation in the governance of agro-industrial firms from emerging economies is an important institutional factor in territories of production that may differentiate firms from Brazil as part of 'latecomer' strategies to compete in oligopolistic industries (Goss, Burch, and Rickson 2000, Goss and Burch 2001, Kingkaew 2014). These initial claims of the existing literature at the level of firm organization, inter-firm relations and firm-territorial interactions provide a starting point to inform thinking on the potentially distinctive aspects of agro-industrial firms from Brazil.

The fundamental obstacle is that we possess scant empirical foundations on the global activities of agro-industrial firms from Brazil on which to construct improved explanations. Aggregate data on outward capital flows from the national accounts of Brazil and other emerging economies provides few clues other than increases in the share of emerging economies as a source of flows to agricultural production and to a lesser extent in food and beverage manufacturing (UNCTAD 2010, UNCTAD 2013). There are also limitations to data on capital flows due to the high degree of geographic and sectoral aggregation, the lumping together of a variety of different flows and firms and the imperfect proxy that this provides for the organization and location of production on the ground. Rama and Martinez therefore argue that firm-level data offers a more detailed view of the global activities of multinational agribusinesses but the dataset

that these authors use does not cover the recent time period of growth of such firms from Brazil and other emerging economies over the last decade (Rama and Martinez 2013). The present research using new and more detailed evidence on agro-industrial firms from Brazil that have branches in Latin America provides an important basis for improved explanations of these processes.

The present study of the world-region of Latin America is central to explanations of firms from Brazil at global scales and allows for the examination of dimensions that recent research from Africa cannot fully capture. The macro-region surrounding the home location of firms has particular significant in agri-food production networks and multinational agro-industrial firms are more likely to concentrate on world-regional rather fully global scales of activities (Filippaios and Rama 2008).[7] Surveys of multinational firms from Brazil that include agribusinesses demonstrate that South America was by far the most important region of activity for a number of indicators of activities of such firms (Fundação Dom Cabral 2014). Other research also suggests that the role of the world-region is different for agro-industrial firms in different locations, with 78% of agri-food acquisitions by firms from Brazil taking place in South America in comparison to firms from China (43%) and India (17%) in their respective regions (Sethi 2009, 360). There are also, of course, differences in language (lusophone vs Spanish) and in research infrastructure, climates, and institutional factors that may differ between Latin America and Africa. The present research from the perspective of the world-region has important implications for explanations of agro-industrial firms from Brazil at global scales as well as a point of comparison to recent lines of research on firms from Brazil in Africa.

[7] Research on agro-industrial firms from emerging economies such as South Africa, Thailand and Indonesia also cite multiple types of important relationships in their respective macro-region (Burch and Goss 2005, Hall 2012).

Research Design

This research addressed these questions by constructing a new dataset of locational and organizational variables of the branches of subsidiary firms in Latin America that were controlled by the largest agro-industrial firms from Brazil in the year 2013.[8] Research on subsidiary firms is an important strategy that analysts used to examine the global activities of large multinational agro-industrial firms from the United States and Europe in the decade prior to the growth of emerging economies since 2005 (Rama 2004, Tozanli 2004, Rama and Martinez 2013).[9] This approach provides a more detailed view of the multi-locational organization of agro-industrial production than is possible with data on capital flows (Rama and Martinez 2013). A limitation of this approach is the potential that underlying sources of evidence on subsidiary firms offer uneven coverage between, for example, publicly-traded firms compared to private firms or between different types of economic activities within a single firm. Despite these limitations, the almost total absence of aggregate data on the activities of agro-industrial firms from Brazil and other emerging economies make this evidentiary strategy a critical building block to improved explanations of these processes.

The unit of analysis of the present research was the branch of subsidiary firms in Latin America that were controlled by the largest agro-industrial firms that had their primary headquarters in Brazil in the year 2013. The sample of firms is based on the geography of the agro-industrial conglomerate as an organization rather than the 'nationality' or geography of

[8] The author culled the list of the largest agro-industrial firms from a basic dataset of the largest one thousand firms in Brazil in the year 2013 that the leading business journal in Brazil publishes on an annual basis (Valor Econômico 2014). This research defined 'agro-industrial firms' as firms or business groups that conducted significant activities in agro-industrial sectors that are defined broadly as input, primary production, agro-processing, wholesale trade, distribution and retail. The present research cross-checked the sectoral designation of the business journal with more specific information from the industrial associations of agro-industrial sectors such as chemicals manufacturing, wholesale, and retail in order to identify firms in particular sectors such as fertilizers (ANDA and ABIQUIM), agricultural machinery (ABIMAQ-CSMIA) and supermarkets (ABRAS).

[9] It is important to remember that this does not include data on other channels through which firms from Brazil affect agro-industrial change in Latin America, such as networked contract relations with other firms that are harder to track empirically, or arms-length relations that requires research based on trade data.

capitals and/or firm management. It also excludes firms that were resident in Brazil but were a subsidiary of a larger business group with a primary headquarters in a location outside of Brazil. This research compiled data on subsidiary firms in Latin America at the more specific level of their multiple physical branch (establishment) locations in order to provide a more spatially and organizationally-disaggregated representation of economic activities than is possible at the level only of the headquarters of the subsidiary firm. Public financial statements, annual reports, websites and third-party information on the agro-industrial group, the subsidiary firm and branch locations provide the source of evidence for locational and organizational data of the branch.[10] This research contributes new evidence that seeks to advance the state of the empirical debate on the actors, locations and basic organization of agro-industrial firms from Brazil and other emerging economies at regional and global scales.

UNEVEN SPATIAL RESTRUCTURING OF LARGE FIRMS FROM BRAZIL IN LATIN AMERICA

This section uses this new branch-level evidence to argue that large firms from Brazil are driving uneven processes of restructuring across space and sectors in Latin America that pivot on agro-industries that are downstream of primary production on the farm. The scope of these branches is a limited number of vertically integrated agro-industrial groups in which meat processors predominate. The location of these establishments reflect multi-scalar processes that unfold at wider scales than in prior eras but also cluster in subnational cross-border regions of the Southern Cone. The organization of these branches specialize in sectors of off-farm processing, distribution and trading that are downstream of primary production, Commodity production

[10] The designation of branch-level data such as the main commodity or sectoral activity are based on a coding rationale developed by the author rather than ISIC sectoral codes or trade in agricultural products and should be interpreted accordingly.

networks center on livestock and, to a lesser extent, on grains. These patterns in the scope, location and organization of firms from Brazil demonstrate the uneven spatial restructuring of a limited number of large agro-industrial firms from Latin America that unfold at new scales and through new production relations but which go beyond undifferentiated claims of the globalization of Brazilian agriculture.

Limited Quantity of Firms but Expanded Institutional Scope

The scope of agro-industrial restructuring associated with large firms from Brazil in Latin America is a limited set of vertically integrated agro-industrial groups in which meat processors predominate but which also include heterogeneous minor trends. This research found that only eleven groups out of a universe of 161 of the largest agro-industrial firms in Brazil in the year 2013 possessed branches in Latin America. Table 4-1 presents the number and financial scope of these groups and their respective branches in Latin America. This evidence shows that these eleven groups possessed 146 branches in Latin America, ranging from firms that possessed only one to three branches to groups such as JBS and BRF that possessed over thirty-five branches in the region. The limited number of large transnational agro-industrial firms from Brazil – the size class that is most likely to organize production beyond the nation-state – and the relatively modest number of branches that these possessed in Latin America indicates that particular drivers explain agro-industrial restructuring associated with firms from Brazil.

The large size of these firms means that activities of one or a handful of organizations may nonetheless have an outsize financial impact on agro-industrial restructuring in Latin America. This is best demonstrated by the firm JBS, which had a revenue of over thirty-nine billion dollars in the year 2013 and which has since become the largest private firm in Brazil and the largest meat processing firm in the world. The evidence of the financial value represented by these branches of groups from Brazil in Latin America is patchy but partial data from 114 of 146 branches

demonstrate that these activities accounted for at least 3.3 billion dollars of net revenue in the year 2013. This paper extrapolates from this partial evidence to estimate that the economic activities of the 146 Latin American branches in these eleven groups represented between five and six billion dollars in net revenue over the course of the year 2013. The economic weight of the largest agro-industrial firms in Brazil underlines the necessity of explaining the global forays of this handful of organizations that represent the vast financial share of agro-industrial processes associated with firms from Brazil across all size classes.[11]

[11] A small but interesting body of research that examines ethnic Brazilian soybean and livestock farmers in locations of Latin America such as Paraguay as well as Bolivia suggests that some of these small and medium-sized firms may base production in Brazil but also operate in Latin America, which is the criteria used by the present research. However, the existing literature does not document the extent of the transnational organization of production - rather than the ethnic basis of management - by these firms. See, for example, the work on so-called mixed-nationality *Brasiguaios* in eastern Paraguay (Galeano (2012a), Blanc (2014) or soybean farmers from Brazil in the state of Santa Cruz in Bolivia (Marques Gimenez (2010), Urioste (2012).

Table 4-1 Brazil-based Agro-Industrial Groups Possessing Branches in Latin America in 2013

Group	No. of branches in Latin America	Total group revenue (current US$ billions)	Latin America revenue (current US$ billions)
Vale	1	43.0	*NA*
JBS	38	39.3	1.0*
BRF	37	12.9	.9*
Marfrig	18	7.9	.9
Amaggi	2	3.6	*NA*
Minerva	5	2.3	.4
M. Dias Branco	2	1.8	*NA*
Cooperativa Vale	3	1.7	*NA*
Camil	29	1.5	.1
Lar Cooperativa	9	1.1	NA
Agrale	2	0.4	*NA*
Total	146	-	> 3.2

Notes: Revenue values converted from the original Brazilian Real based on Brazil Central Bank exchange rates on 12/31/12. Latin America revenue values may contain minor distortions related to the attribution of earnings of subsidiary firms to the conglomerate. * Values with an asterisk indicate partial figures based on available data for only one of the multiple countries in which these groups possessed branches in Latin America.

At a global scale of operations, these eleven groups vertically integrate primary production but concentrate in activities downstream of the farm and to a far lesser extent in sectors that are upstream of primary production. Figure 4-1 presents a stylized depiction of the vertical integration of production processes by the global operations of these groups. The cell location of the name of the firm indicates the predominant sector of operation of the respective group. These are large corporate business groups that organize operations through a web of subsidiary firms across a range of downstream and upstream agro-industrial sectors as well as sectors outside of agro-industry such as transportation, mining and others. The vertical integration of these large conglomerates demonstrate that explanations of agro-industrial and land-based changes associated with the regional and global activities of firms from Brazil require frameworks that extend beyond the activities of farmers.

The commodity composition of the global operations of these agribusiness groups represent a specialization of these organizations in beef and poultry processing. This is best expressed by the beef processing giant JBS as well as BRF, which was formed from a merger of two large chicken processing firms in Brazil. It also includes the groups Marfrig and Minerva that operate in bovine commodity networks. Analysts of business economics have begun to study the global strategies of these meat processing groups but there is still scant literature that examines their regional and global scales of activity (Pigatto and Santini 2009, Honorato Teixeira, Estima de Carvalho, and Feldmann 2010, Stal, Sereia, and Cesso da Silva 2010, Pereira Pelláez 2012, Spohr and Freitas Silveira 2012). Explaining the spatial restructuring of agribusiness from Brazil in Latin America is therefore principally a question of deepening explanations of the logics of these groups in meat complexes and the multiple territories across which they organize production.

Figure 4-1 Extent of Vertical Integration of Agro-Industrial Groups from Brazil, 2013

Inputs	Primary	Manufacturing	Trade	Retail	Other
					Agrale
					Vale
	Coop Vale				
	Lar Coop				
		BRF			
		Camil			
		JBS			
		M. Dias B.			
		Marfrig			
		Minerva			
			Amaggi		

This new evidence on agribusiness groups from Brazil also reveals a more heterogeneous set of firms than exists in the literature on the globalization of agribusiness in Latin America. Three groups specialize in grains but present different logics of operations in Latin America: the group Camil Alimentos specializes in rice as well as sugar processing, M. Dias Branco is a manufacturer

of cookies and crackers and Amaggi is the largest soybean firm based in Brazil. The business groups of Agrale, a manufacturer of machinery, and Vale, a global mining leader, indicate that changes in agro-industry require a wider frame of analysis that includes large horizontally integrated conglomerates whose primary sector of activity is outside of Agro-industry. Cooperativa Vale and Lar Cooperativa are a new finding of multi-locational cooperatives from Brazil that aggregate a transnational organization of small or middle-sized firms across borders in the Southern Cone from bases in places such as the Brazilian states of Paraná, Rio Grande do Sul and Mato Grosso do Sul (Galeano 2012b, Urioste 2012).[12] These minority trends are shaping processes of agro-industrial restructuring in Latin America that the existing literature does not address and which necessitate explanations of a broader set of logics by a more heterogeneous set of actors beyond the large meat processors.

The restructuring of groups from Brazil in Latin America was primarily through acquisitions of existing companies in Latin America rather than greenfield investments. Approximately 90% of branches for which data is available (95 of 105) resulted from acquisitions of companies in Latin America. New branches represented only 10% although the data suggests that the constitution of new branches is perhaps a more common mode of rescaling for wholesale trading operations. The importance of acquisitions as the mode of restructuring is in line with existing research on the importance of acquisitions by agri-food firms from Brazil in Latin America (Sethi 2009). This finding indicates that the spatial restructuring of groups from Brazil in Latin America is part of a regional-scale process of agro-industrial concentration in Latin America and is consistent with wider arguments concerning the reproduction of agro-industrial concentration (Wilkinson 2009).

[12] It is important to note that the net revenue of JBS is between twenty and one hundred times the size of even large firms such as Agrale, Lar Cooperative and Cooperativa Vale, Camil and M. Dias Branco.

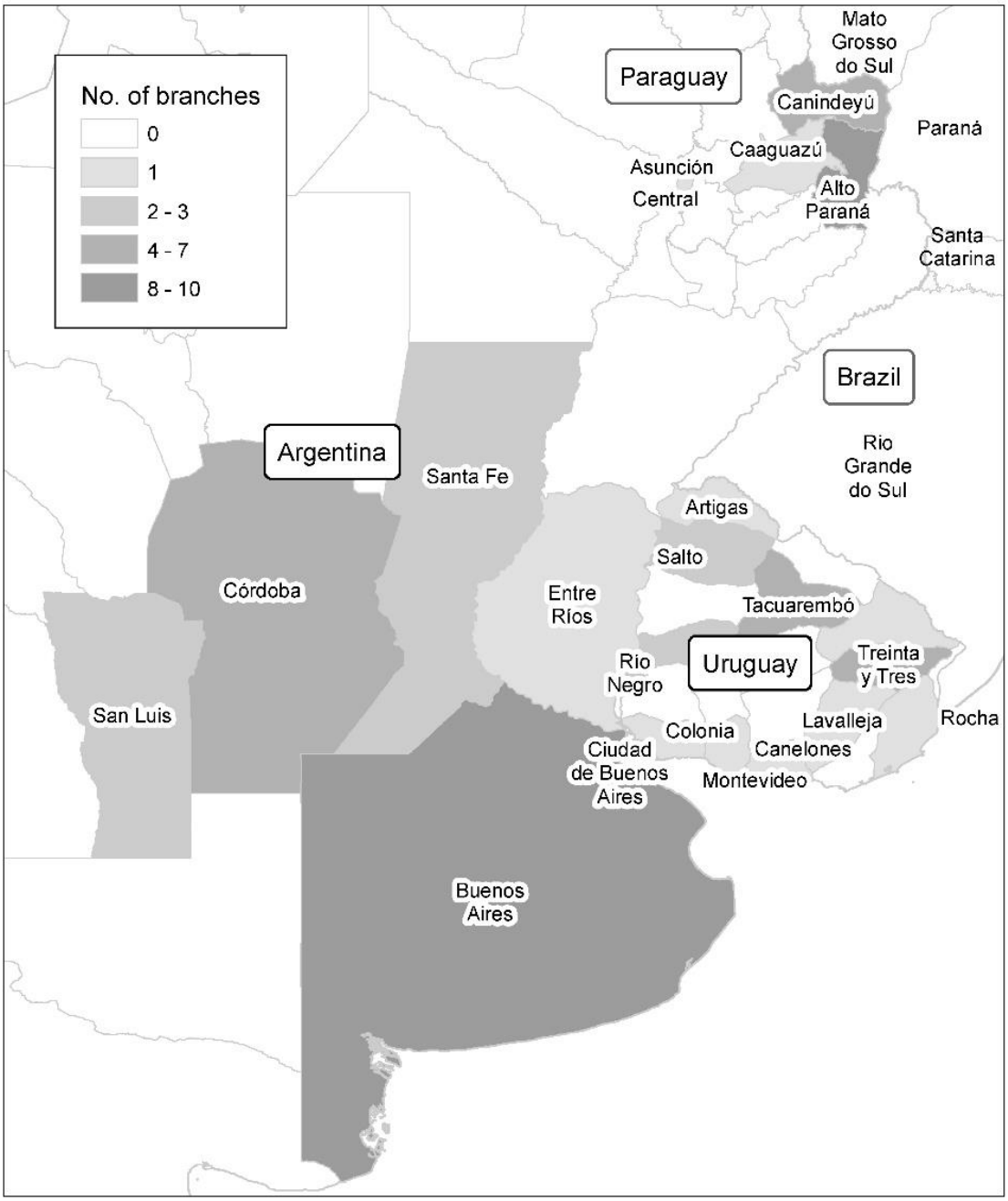
Multi-Scalar Subnational Locations Within the Southern Cone and Farther Afield

This new branch-level evidence from Latin America reveals new multi-scalar patterns of restructuring of multinational agribusiness from Brazil. Figure 4-2 displays the spatial distribution of agro-industrial groups from Brazil in Latin America in the year 2013 for 105 branches for which data is available. This data shows wider regional scales of activity in a limited set of locations, but also cross-border regional clustering in a few subnational areas within the Southern Cone. These findings represent new spatial dynamics of agro-industrial firms from Brazil. However, these results are also more limited than a generalized dispersion of production across Latin America that analysts sometimes imply in their narratives on the globalization of agricultural actors from Brazil.

Figure 4-2 Location of Latin America Branches of Agro-Industrial Groups from Brazil, 2013

Agribusiness groups from Brazil are organizing production at wider spatial scales in comparison to previous decades. This comprises scales of economic activity that analysts have not previously documented and which extend beyond cases of cross-border dynamics related to smaller agricultural firms in the Southern Cone and along borders with countries such as Bolivia and Paraguay (Galeano 2012a, Urioste 2012). In 2013, a single group from Brazil possessed a branch in Colombia, three groups possessed seven branches in Peru, and five groups possessed twelve branches in Chile. There were also twenty-seven branches in central Mexico associated with a single group, which represents a new outlying dynamic of firms from Brazil that are operating outside of South America. Agribusinesses from Brazil are operating at wider scales but these are limited cases in particular locations rather than a general dispersion across Latin America.

Figure 4-3 Location of Branches in Southern Cone, by Subnational Administrative Division, 2013



The second trend is the spatial clustering of branches in subnational and cross-border regions in the Southern Cone of South America. This clustering represents a separate and in some ways countervailing locational logic from that of the distribution of branches across greater scales of South America and into Central Mexico. Figure 4-3 shows the distribution of 68% of the total number of branches of agribusiness groups from Brazil in Latin America across just twenty sub-national administrative divisions in the Southern Cone.[13] This includes six provinces in center-eastern Argentina, four departments in eastern Paraguay along the border with Brazilian state of Paraná and in the capital region, and across ten departments of Uruguay. The existing literature on border spillover processes among small and medium farmers in Paraguay since the 1970s does not fully explain this deepening of the locational logic of the largest groups from Brazil in the Southern Cone.

A significant number of branches of agribusiness groups locate in urban areas and along water-based export corridors rather than in deep rural frontiers. This includes the administrative and financial centers of the national capital cities of the respective countries in which branches were located. This also consists of smaller secondary cities, for example in central Mexico or gateway cities to regions of primary production and transport networks in the Southern Cone. Branches are also located on or near water transport routes, particularly the Paraná-Paraguay inland export corridor in the Southern Cone but also in coastal locations of Peru, Colombia and Chile. In one sense, these locations are consistent with explanations based on transactions and transport costs but they are novel in that firms from Brazil express significant urban logics in Latin America in combination with traditional explanations based on the location of farms and soils.

[13] This figure is based on the 105 branches for which specific locational data is available

Livestock Commodity Networks Predominate

The commodity networks of Brazilian firms in Latin America concentrate heavily in economic activities associated with bovine and poultry production. Table 4-2 shows the primary commodity network for 105 branches in Latin America for which data is available as well as the value of primary production for the corresponding commodity in Brazil. Approximately one-third of branches participate in bovine production networks and one-third in poultry networks. This finding represents a more pronounced livestock commodity specialization than existing accounts that emphasizes the global activities of Brazilian farmers in agrarian change in Latin America through soybean farming in border regions of Paraguay and Bolivia (Galeano 2012a, Urioste 2012). Analysts in Brazil have described the activities of livestock processing firms from Brazil in Latin America but this evidence represents a new finding of the particular predominance that these commodity networks represent in the role of firms from Brazil in Latin America more generally.

The globalization of groups from Brazil in Latin America was only marginally associated with so-called flex crops such as soybeans or sugar cane that are leading crops in Brazil in terms of production and export value. Approximately one-third of the branches for which information is available were associated with grains production. A more particular trajectory of private equity-fueled acquisitions of localized consumer brands in South America made rice the commodity network associated with the greatest number of different branches in Latin America, with seventeen locations. There is evidence of two branches in soybean and corn production and two branches in wheat but these are quite limited results in comparison to the predominant drivers of livestock firms. There is no evidence of branches in Latin America in other leading production and export commodities from Brazil such as sugar, coffee, oranges or pork. These activities – and absences - of agro-industrial groups from Brazil in Latin America reflect an array of firm and industrial dynamics that cannot be read-off from simple correlations with the leading commodities

produced in Brazil nor comparative advantages for the production in ‘exotics’ in specific agro-climatic locations that only exist outside of Brazil.

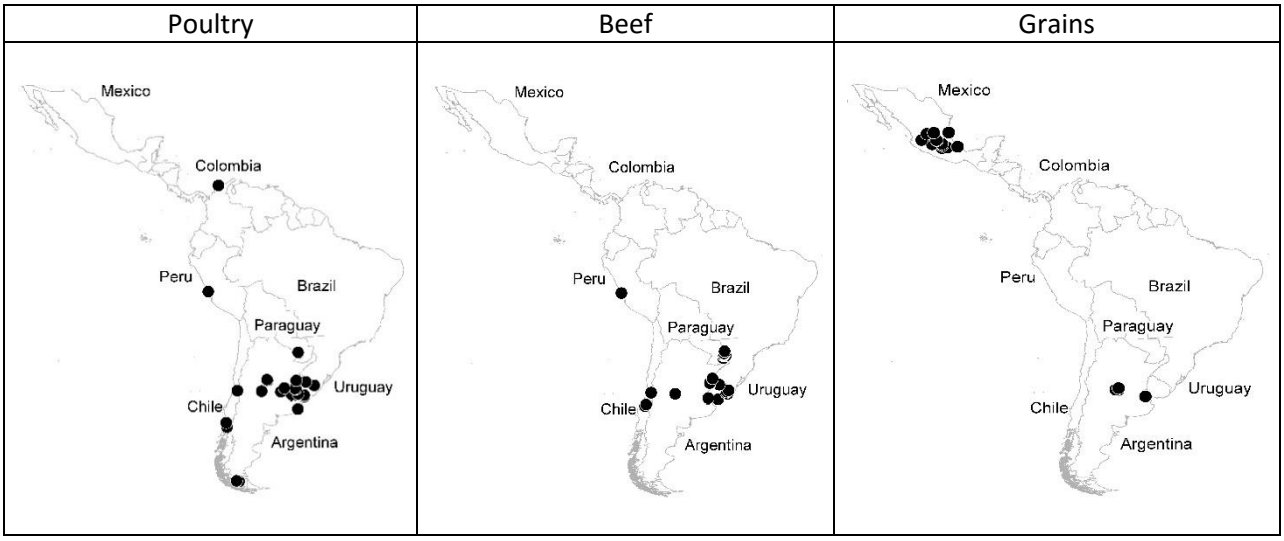
Table 4-2 Number of Branches in Latin America and Production Value in Brazil, by Commodity

Commodity network	Number of branches in Latin America (2013)	Value of primary production in Brazil (2012), US$ billions*
Livestock	66	-
Bovine	32	26
Poultry	33	32
Unspecified livestock	1	-
Grains	32	-
Rice	17	2
Soybeans**	2	14
Wheat	2	.9
Unspecified grains	13	-
Dairy	2	6
Unassociated	5	-
Unspecified/unknown	41	-

Sources: (FAO 2012)

Notes: * Value of production is in 2004-2006 constant US$ ** also include corn and wheat

Figure 4-4 Location of Branches of Agro-Industrial Groups from Brazil, by Commodity, 2013



These different commodity groups also exhibit distinct locational patterns. Figure 4-4 shows the spatial distribution of branches in Latin America for beef, grains and poultry commodity networks. Branches that are part of bovine and grains production networks are concentrated primarily in the Southern Cone in overlapping locational patterns. Branches associated with poultry production networks are concentrated in a quite different set of locations in eastern Argentina as well as in Central Mexico. These broad-view spatial patterns indicate the importance of understanding the particular economic geographies of different commodity complexes associated with firms from Brazil. At the same time, these also call analytical attention to the way that livestock production networks may co-locate in areas of crop production for animal feed.

Specialization in Processing, Distribution and Trading

One of the most significant findings of this research is that agro-industrial groups from Brazil in Latin America specialize in agro-industrial sectors that are downstream of primary production on the farm, with processing as the predominant sector of activity. Table 4-3 presents

the distribution of branches in Latin America according to the predominant economic sector of activity conducted by these branches in the year 2013. Evidence shows that at least 78% (114 of the 146) of branches specialize in economic sectors that are downstream of primary production. agro-industrial processing, with 35% of branches (52 of 146), represents the greatest economic sector of specialization in Latin America. This includes primary as well as some secondary processing activities along livestock production networks although food manufacturing more generally and rice milling are also examples of these activities in grains networks. The relative share of processing in the total sectoral composition of the activities of groups from Brazil in Latin America is a significant finding that requires closer attention to the development of agri-food and agro-industrial manufacturing sectors in the region.

Table 4-3 Economic Specialization of Groups from Brazil in Latin America, by Sector, 2013

Main sector of activity	Number of branches	% of total
Processing	52	35%
Distribution	45	31%
Trading	17	12%
Unspecified commercial / administrative	13	9%
Primary	7	5%
Inputs to primary production	3	2%
Other / unspecified	9	6%
Total	146	100%

Distribution and trading of agro-industrial products are the primary economic activity in 43% of branches. Over half of the branches in Latin America specialize in distribution, intermediation and trading of agro-industrial products if we add to the above figure the unspecified commercial activities of branches as well as transport-related activities in the category of ‘other.’ This includes distribution and trading of livestock through groups such as JBS and BRF as well as firms that operate in grains. The Amaggi group recently established branches in Paraguay and Argentina for

the sourcing of soybean, corn, and cotton after pulling out of primarily production activities (Amaggi 2014). The activities of agro-industrial groups from Brazil in Latin America are not predominantly as farmers but rather through the activities of particular downstream sectors.

The importance of distribution, trading activities as well as unspecified commercial activities signal the importance of the organization of intra-group trade in the activities of these groups in Latin America. This includes networks for domestic consumption, for example of poultry products to the Mexican market as well as trade of inputs such as wheat to food production in Brazil. However, consumer markets in Brazil and Latin America do not appear to be the only or even the primary focus of these branches. A complete set of data on the final destination of products of branches in Latin America is outside of the scope of the present research but evidence from trade records and company reports indicate that a significant portion of these branch activities are oriented to third markets outside of Latin America and Brazil. It is important to approach these regional production networks between Brazil and Latin America not as closed production systems but, rather, as economic nodes in intra-group trading organizations that are often organize at global scales.

The spatial restructuring of the largest agro-industrial groups from Brazil does not directly occur through farming. The importance of commercial activities such as the intermediation of grains outweighs that of integrated branches that conduct primary production. This research found evidence that only 5% (7 of 146) of branches engage principally in primary production. This research may undercount the extent of integrated primary production activities that are secondary to agro-industrial processing units at a particular branch but there is little indication that these would represent a markedly different share than found in this study. The limited importance of primary production represents a significant finding that diverges from much of the existing research on the globalization of agribusiness from Brazil in Latin America and Africa.

The lack of evidence of branches in agro-industrial sectors that drive restructuring along production networks may also indicate the limits to the power of agro-industrial groups from Brazil to influence production in Latin America and globally. In input sectors, there was one branch in

southern Peru dedicated to the mining of inputs for the production of fertilizers as well as one agricultural machinery assembly plant in the province of Buenos Aires in Argentina. The finding that there were no branches in which the predominant economic activity was agri-food retail contributes to literature on supermarket-driven restructuring by providing further evidence that even Brazil's largest domestic supermarket groups such as Pão de Açucar did not follow the Latin America acquisitions strategies of globalizing groups such as France's Casino and Carrefour (Reardon and Berdegué 2002, Reardon, Henson, and Berdegué 2007). There were also no branches in which the principal economic activity was research and development, which is a finding that provides insights to research on the organization of innovation by agri-food multinationals from emerging economies (Burch and Goss 2005, Rama and Martinez 2013). The absence of branches in Latin America in retail and other innovation-driven sectors such as seeds are significant findings that qualify the general findings of the off-farm specialization of groups from Brazil.

This new branch-level data provides new evidence that the activities of agro-industrial firms from Brazil in Latin America are uneven in the types of actors, their locations and the industrial organization of the sectors and commodity production networks that these represent. The *scope* of these processes are limited to a handful of vertically-integrated and sometimes very large agro-industrial groups from Brazil, of which meat processors are the predominant driving force. The *location* of these processes is multi-scalar, both through wider scales than previously documented but also through a spatial clustering in subnational cross-border regions of the Southern Cone. The predominant economic specialization of groups from Brazil in Latin America is in downstream sectors of processing, distribution and trading along beef and poultry production networks rather than land deals for primary production, a retail 'supermarket revolution' or a transnationalization of Brazilian farming of flex crops. The next section discusses these patterns and their implications for explanations of these trends in light of existing literature.

These insights on the scope, location and organization of the largest agribusiness groups from Brazil inform explanations of agro-industrial restructuring and, by extension, agrarian and land use change in Latin America. This new branch-level data from Latin America reveals a broad shift in the spatial division of labor in large agribusiness groups from Brazil in comparison to previous eras. These groups established only three out of 108 branches in Latin America for which evidence is available prior to the year 2005. This evidence also shows the deepening of Southern Cone production logics by large agro-industrial firms from Brazil despite the existence of Mercosur integration processes since the 1990s. These are not just the spatial outcomes of restructuring processes but also new combinations of territorial influences that require us tweak the standard explanations of Brazilian agricultural production systems in terms of southeastern, center-west or northeastern regions of Brazil.

These new locations are not merely ‘old Brazilian crops in new foreign silos,’ to adapt the winemaking metaphor. Rather, these new spaces of agro-industry encompass more markedly industrial sectors, more global livestock commodity networks and a broader set of production relations that differ from explanations of export agriculture from Brazil in the previous period. The degree of vertical integration and the pronounced specialization of branches in Latin America in downstream sectors comprise new dynamics of production that require alternative approaches to global firms from Brazil as processors, integrators, logisticians and traders. These global livestock production networks involve a wider set of intra- and inter-firm production relations in comparison to export crops or domestic livestock systems in Brazil in previous eras. As the largest agro-industrial firms from Brazil move beyond the borders of the nation-state these conglomerate groups require new frameworks of analysis that extend beyond the unit of the farm.

These findings of the off-farm composition of rescaling processes do not obviate the role of firms from Brazil as drivers of agrarian and land use change. These new roles of large

agribusiness from Brazil include a broader set of indirect drivers of land-based change in Latin America. This requires different analytical frameworks than previous explanations of 'high-value crops' or even more recent focus on firms from Brazil in a global biofuels expansion (Dauvergne and Neville 2009). There is a considerable literature on firms from Brazil in domestic cattle frontiers but the combinations through which rescaling and coupling of livestock-grains production systems unfold in South America is still poorly understood (Gasparri and le Polain de Waroux 2014). Despite the global reach of meat processing groups from Brazil through integrated and networked operations, these do not always lead to global convergence in production frontiers but, rather, continue to produce multiple and shifting relationships that have different types of implications for land-based changes in Latin America (Gasparri and le Polain de Waroux 2014, 4).

The downstream specialization of these branches in Latin America indicates that a more varied set of relationships to primary production mediate the role of firms from Brazil as drivers of agrarian change. These groups are indirect drivers of changes in primary production, which require frameworks of analysis on the sourcing strategies of slaughterhouses, the intra-firm trading networks in soybeans, and the contract farming schemes that feed poultry distribution networks. There are no existing studies of these networked relations of large agro-industrial firms from Brazil in Latin America and there is little research on the contract relations of agro-industrial firms from other emerging economies (Burch and Rickson 2007). The activities of these firms require new lenses to the multiple ways that agro-industrial organization articulates with primary production and shapes land tenure, including through networked relationships with farmers as well as acquisitions in real estate sectors that are outside the scope of the present research.

The implications of this evidence for questions of the divergence of firms from Brazil from theories associated with firms from the United States, Europe or other emerging economies are less conclusive and require additional research. While these cases represent new spaces and places of agro-industrial restructuring, many of these patterns do express convergence to the patterns of large multinational firms from other places, whether through purposive replication or institutional change in the face of concentrated mature agro-industrial sectors (Wilkinson 2009).

Evidence that branches conducted an expanded scale of economic activities that these groups also conducted in Brazil is consistent with a search for scale economies in similar ways to multinational agro-industrial firms from the United States and Europe (Chevassus-Lozza and Galliano 2009).[14] The establishment of new wholesale trading branches, for example in grains, is consistent with geographic diversification of risk and an increase of control across multi-stranded production networks in similar ways to the sourcing practices of the large grains traders from the United States and Europe. However, while it may be broadly true, as Wilkinson argues, that "for the farmers and public it will make little difference whether the oligopolies are in the hands of Brazilians or foreigners," the multiple sources of uncertainty – geopolitical, economic, technological and climatic – in the present moment of agro-industrial restructuring requires that we approach these new processes as unsettled empirical questions.

With a view to this agenda, this section offers three hypotheses to guide subsequent research on the ways that these processes diverge, even if only in partial ways, from existing theories based on cases in different eras and places. First, groups from Brazil, a powerful producer country, may develop distinct *intra-firm organization* based on the logic of establishing export platforms in Latin America in order to circumvent tariffs and trade conventions in final markets of consumption to direct exports from Brazil. This line of argument claims that groups from Brazil acquired a large number of branches in Uruguay and Argentina to function as export platforms for products that faced more restrictive sanitary or tariff barriers from Brazil (Farina and Reardon 2000, Honorato Teixeira, Estima de Carvalho, and Feldmann 2010, Stal, Sereia, and Cesso da Silva 2010, Arenaro e Mello Dias, Caputo, and de Morais Marques 2012, Pereira Pelláez 2012, Spohr and Freitas Silveira 2012). This argument that hinges on the final market of production networks involving firms from Brazil is similar to Kaplinsky and Farooki but these

[14] There is little indication that comparative advantage in factor endowments between Brazil and the locations of subsidiaries in Latin America explain these processes. There were two branches in Latin America that source wheat, a temperate crop, as an input to food manufacturing in Brazil but these are limited cases. There is also no suggestion in company documents and the existing case study literature that labor costs in manufacturing were significant factors. Analysts also pay little attention to tax advantages or regional trade agreements within Mercosur as significant explanatory factors of these processes.

authors suggest the opposite logic of the downgrading of standards in agri-food trade to China and India whereas firms from Brazil continue to orient an important share of trade to markets outside of Asia. The hypothesis of divergence from cases in other locations is that an export platform logic of firms from Brazil differs from agribusiness from the United States that offshored segments of production based on cost and climatic factors to regions in Mexico or Central America rather than reorganizing production to circumvent global trade restrictions.

Second, differences in *inter-firm relations* in particular territories in Latin America where groups from Brazil locate branches may represent endogenous sources of influences on wider scales of agro-industrial restructuring. In this argument, the location of branches of groups from Brazil in the Southern Cone may express knowledge spillovers that are one of the dimensions of agglomeration economies – the benefit that firms gain from geographic proximity to one another. For example, analysts of multinational food manufacturing firms in other locations have found evidence that suggests that technological and informational spillovers led to positive variation in export performance (Chevassus-Lozza and Galliano 2003).[15] The evidence for this line of argument is the claim that the processing and trading branches in the Southern Cone represent longer-term upgrading strategies for groups from Brazil through their purposeful insertion into industries with institutional innovations in sanitary certification as well as specialist IT and technical services (Pittaluga et al. 2014, Rius 2015). The importance of innovations related to agri-food conventions as a logic of the rescaling of agro-industrial groups from Brazil is also suggested by researchers who argue that multinational firms from emerging economies may acquire innovations through their branches at wider scales (Rama and Martinez 2013, Cazurra and Ramamurti 2014). The logic of divergence from other cases is that explanations of the global economic geography of Brazilian agro-industrial groups may hinge more on rescaling to advanced agro-industrial clusters rather than groups from the United States and Europe that possess more advance technologies and offshored primary production to frontiers at regional scales in Latin America.

[15] However, see also Schmit and Hall (2013).

Third, distinct *firm-state* relations of governance agribusiness from Brazil influence divergent forms of restructuring of agro-industrial production networks in comparison to groups from the United States and Europe. The most prominent cases of agro-industrial policy via the financing of firms in Brazil over the last decade involved support that the Brazilian National Economic and Social Development Bank (BNDES) provided to livestock processing firms in the present research (Jesus Junior, Raposo Correa, and Lima de Paula , Stal, Sereia, and Cesso da Silva 2010, Arbix and Caseiro 2011, Maristrello Porto and Nogueira 2012, Kingkaew 2014). Analysts argue that the role of states in emerging economies differ from those in the United States and Europe but we also require additional research beyond financing to areas such as innovation, sourcing agreements and global trade governance in the cases of firms from emerging economies (Goss, Burch, and Rickson 2000). The logic of divergence in this argument is that the state-firm relations of governance of agro-industry in Brazil differ from those in Europe and the United States in ways that influence different outcomes of agro-industrial restructuring at wider scales.

This new evidence of the actors, location and industrial organization of the production footprint of the largest agro-industrial firms from Brazil in Latin America in the year 2013 offers new answers to the questions that researchers asked of agro-industries from Brazil and other 'new agricultural countries' in the 1990s. These wider set of scales and more industrial sectors encompass new production relations and institutional arrangements that have implications for existing explanation of agro-industrial and land-based change. This paper argues that these production relations and institutional arrangements are still poorly understood and should be approached as empirical questions that can refine our existing explanations of agro-industrial restructuring based on firms from the United States and Europe in previous eras. This research suggests three dimensions of inquiry based on particular forms of intra-firm organization, inter-firm relations and firm-state governance in order to inform explanations of the ways that firms from emerging economies continue to produce differences in global-processes of agri-food restructuring. These hypotheses seek to provoke new rounds of theoretically-informed enquiry on the activities of agro-industrial firms from Brazil at regional and global scales.

CONCLUSION

This paper advances the state of the debate on the spatial restructuring of agro-industrial firms from emerging economies by examining new evidence on the largest such business groups from Brazil in Latin America. These new empirics at the level of the branch of the subsidiary firm in Latin America represent the first evidence of the production footprint of the largest groups from Brazil on the ground in Latin America across a wide range of agro-industries. This contributes significantly more specificity on the actors, location, commodity networks and sectoral composition of production processes than is possible with existing data on capital flows. At the same time, the wider sectoral and geographical frame of this research provides a more representative set of aggregate information that throws new light on existing case studies from a more limited selection of sectors and geographical locations. This paper contributes an empirical foundation on which to build improved explanations of global processes of restructuring associated with large agribusinesses from Brazil.

This paper reconceptualizes the activities of agribusiness from Brazil in Latin America as an uneven and limited process of spatial restructuring of production rather than a process of globalization that can be read off from the dynamics of export agriculture in Brazil or the growth of Brazil as an emerging economy. The finding that there is a limited number of large vertically-integrated conglomerates from Brazil that possess subsidiary branches in Latin America redirects debates on Brazilian firms in Latin America to the differentiated types and size classes of organizations that produce at scales beyond the nation-state. The evidence of multi-scalar processes that predominantly cluster in a handful of locations within the Southern Cone and only sometimes extend farther afield refocuses analytical lenses to the sub-national and supra-national dimensions of restructuring of agribusiness from Brazil in Latin America. Branches that predominantly specialize in processing, distribution and trading along beef and poultry commodity

networks serve to move our analytical lenses beyond ethnic Brazilian farming of the type that analysts have documented in regions along the borders of Brazil.

This paper advances the theoretical debate from the existing focus on novel emerging geographies of agro-industrial restructuring toward analytics of how and why new locations of firms from emerging economies may involve quantitatively or qualitatively different processes of restructuring in an array of industries and crops at regional and global scales. The global production networks framework utilized in this paper helps to unify debates that fracture between firm-specific explanations in business economics and territorial-specific studies in agrarian political economy. This approach also integrates case studies of agro-industrial restructuring into wider conversations with literature on industrial organization and location. This paper moves toward more specific explanations of these processes by suggesting three aspects of research on the ways that firms from Brazil may be distinguished from restructuring processes associated with firms from other places and eras. These includes differences in intra-firm organization of trading networks, inter-firm agglomeration economies, and territorial-based forms of firm-state governance. These dimensions of enquiry organize new debates around the institutional arrangements that influence why groups from Brazil diverge from existing explanations of regional and global-scale processes of agri-food restructuring.

Improved explanations require new rounds of targeted research on how and why these processes unfold at the level of particular firms, sectors, production networks and places in the light of this new evidence. This includes comparative research on temporal changes in firms or sectors in Brazil or between the activities of particular firms from Brazil in comparison to firms in similar sectors in the United States or China. This paper addresses gaps on the integrated operations of controlled subsidiaries but *a*dditional research is required on the wider production networks of these firms, of which there is scant evidence (Burch and Rickson 2007). There were also financial drivers behind the spatial restructuring of large agro-industrial firms from Brazil in less-examined sectors such as rice that were beyond the scope of the present paper. Subsequent research is necessary to explore the ways that production processes in this case are shaped

through the finance and financialization of agro-industry. We can learn much from a world-regional perspective but this evidence also shows that firms from Brazil in Latin America do not constitute a closed production system and additional research is required on the way that these regional nodes of agro-industrial restructuring relate to global-scale processes of competition and consumption with firms in the United States, Europe and Asia. Expanding our toolbox of approaches to the recent processes of spatial restructuring of large agro-industrial firms from Brazil will improve our explanations of the emerging dynamics that will shape agro-industries and land-based processes of change into the future.

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Chapter Five. Conclusion

This dissertation began on the wings of presidential planes but now concludes at a moment of turbulence in the wake of the recent "emerging" era of growth in tropical agro-industrial systems within Brazil. At the time of writing, the delayed effects of the global economic downturn of 2008 and a more particular crisis of graft extends into the center of national political and economic institutions in Brazil and, by extension, into relations with Latin America. The decrease in Chinese demand is straining commodity producers in Brazil and Latin America but previous eras of volatility in the 1980s and 1990s also suggest that the spatial restructuring of varied sub-sectors and territories within these systems will not move in lock-step with aggregate sectoral or economic trends. These economic and political changes also introduce new dynamics into the recent aggregate trend of declining forest loss in Brazil, which had already defied conventional predictions by unfolding in parallel to the surge in agricultural production (Hecht 2014). The current juncture is, in short, one of considerable uncertainty for scholarly models as well as interventions into growth and environmental conservation.

The inter-regional learning matrix provides a new conceptual framework and set of empirics through which to interpret geographical shifts in tropical agro-innovation in the recent era and across this transitional moment into the future. Extensive multi-sited fieldwork and alternative data collection strategies in these three studies produced more granular evidence that establishes the multi-locational dimension of regional agro-industrial production systems within Brazil. The framework of learning from multiple varied locations within the Americas provides a complement to the growing literature on endogenous systems of innovation at the territorial scale within Brazil and de-centers the existing dichotomy between a national Brazilian system of innovation and an international system of agricultural technology transfer that was developed for Latin America

during a different context after the second world war. This framework also mobilizes explanations of local innovation within hotspot locations and calls attention to the agency of local actors and the mobility of knowledge in sectors that scholars too often treat in terms of a static locational specificity.

This conclusion proceeds by reviewing the implications of the findings for the framework of an inter-regional matrix of learning. The following section discussions the contributions of this dissertation to the literature as well as the implications that this has for key debates on economic organization, environmental conservation and governance. The next section details the outlines of a research program on inter-regional matrix and addresses issues for subsequent research. The final section discusses implications and recommendations for select aspects of policies and practices.

CONSTRUCTING A FRAMEWORK OF THE MATRIX OF TROPICAL AGRO-INNOVATION

This dissertation outlined an analytical framework of an inter-regional learning matrix as a complementary dimension of endogenous agro-innovation in subnational hotspots within Brazil. The three studies began “on the ground” with multi-locational agents in order to establish part of the conceptual architecture of this matrix. The two different types of scientific agents of innovation at two different levels (individuals and organizations) address two of the most important agents of innovation with tropical agro-industrial systems within Brazil.

What are the implications of the findings of the three studies for the construction of this matrix? Chapter two developed the general concept of *regional systems of circulation* to demonstrate the regional foundations of mobility of plant scientists and the governance of this channel of learning was a mechanism that contributed to the construction of agro-regions of Minas

and Cochabamba. Chapter three integrates the relations of mobility into an explanatory framework of the key agents of EMBRAPA scientists and illustrates a more varied set of sectors and environmental frames of knowledge activities that stretch beyond linear science. Chapter four makes new relational geographies of learning visible by producing new empirics on subsidiary branches and the inter-regional lens constructs new interpretation of organizations from Brazil. We can review aspects of the conceptual framework developed through these three studies.

Regional Systems of Circulation: Situate "Emergent" Mobilities in Regional Histories

The novel concept of a *regional system of circulation* developed in chapter two situates the recent "emerging economies" approaches to the globalization of South American agro-industrial systems into a longer historical timespan of territorially-embedded learning across space. The comparative findings from the regional histories of two systems in South America ground the matrix approach to the recent era of globalization and climate change within a more general multi-scalar dimension of tropical agricultural regions. The larger lesson from this chapter is that extra-regional learning through mobility is a more general process within tropical regions but also that these processes arrange in different ways across time and space and with different implications for the home region. The circulatory system approach in this chapter also establishes the social basis of inter-regional learning by introducing "local" agents into a historical literature that revolves primarily around the mobility of material technologies from the tropics but the immobility of "local" knowledgeable individuals from the tropics, especially when compared to the approaches to cases of knowledgeable "explorers" from locations in the United States and Europe. This approach to the "outward" dimension of mobility provides a more robust explanation of global dimensions of localized agricultural change that traditionally are attuned only to the "inward" movement of agents from the United States and Europe into tropical regions.

Nor do historical processes recede into the distant past. The findings from this study may also suggest that regions that learn in extra-regional situations over time may develop capabilities that are transferrable to other contexts, eras and geographies. The University of Viçosa at the center of the mobility of corn scientists in the 1930s was also one of the organizations that in the late 1990s was associated with the transnational organization of medium-sized soybean and farming firms from Brazil into the Santa Cruz and Beni eastern regions of Bolivia. The persistence of formalized relations of collaboration between researchers at Viçosa and Purdue University in West Lafayette, Indiana that were established in the late 1940s is another example that points to historical construction of current-day differences in capabilities of extra-regional learning. These examples distinguish the Minas Gerais case from comparison cases of university-regions within Brazil and suggest that part of the explanation of the recent processes lies in the distant past of a larger regional arrangement of extra-local learning capabilities. The partial transferability of regional capabilities of extra-local learning to a wider set of distant locations.

Agent-based Mobilization of Inter-Regional Channels

The three studies explain the social construction of extra-regional learning channels by heterogeneous individuals and organizations of innovation. One general implication of this analytical lens is to draw analytical attention to the agency of individuals and organizations from tropical regions to change their insertion into globalized processes of knowledge construction. At the same time, the approach to university scientists in chapter two, public research institute scientists in chapter three, and subsidiary branches of large agro-industrial firms in chapter four also represent the argument that mobile agents of innovation from tropical regions are both plural and heterogeneous. These choices of agents are also not exhaustive. dissertation advance our knowledge of the present moment because they build up from the ground with the activities of different mobile agents.

Non-Linearity of Learning within Inter-Regional Channels

An important general finding from the contrast between agents in chapters three and four is that multi-locational agents from the same country or region within Brazil do not move as a monolith and do not neatly map geographically or sectorally onto each other. The EMBRAPA scientists in chapter three moved over recent years to a broader set of locations across Latin America in contrast to the siting of subsidiary branches in chapter four in a more limited set of locations within the Southern Cone or in particular cities of subnational regions. These also express different production networks and knowledge specializations, with the activities of EMBRAPA scientists comprising non-traditional networks and dimension of production that are not expressed by subsidiary branches that center on a more limited and traditional set of meats and grains networks. This finding on locations and sectors suggests that heterogeneous agents that form a single matrix or inter-regional channel do not express a single logic of learning. The empirics in this dissertation challenge approaches that focus on more aggregated spatial or organizational units of analysis and help to construct a more accurate framework for analysis of cross-border activities. The inter-regional matrix provides an interpretation of these findings as mobile processes of learning of different multi-locational agents that come together in home regions of Brazil. These may not be expressed in cross-border activities. One interpretation of this is a temporal expression of a linear model of the internationalization of firms in which EMBRAPA scientists abroad in 2013 may learn from new emerging production networks or opportunities that they share with large agro-industrial firms that move to similar opportunities across borders. A second consideration in interpretation is that the studies in the two chapters express different units of analysis, at the individual level versus the level of a branch location. These are likely to express more varied but unobserved mobile processes of learning of different employees within a firm. This is a point for further research.

Quality of Relations and Knowledge

A simple aggregation of the mobility of agents does not sum to an inter-national model of innovation. The findings of social *mechanisms* of knowledge spill-ins should be distinguished from a simple aggregation of agents as part of a *mechanistic* casual model that flows from the multi-locational movements of innovative agents from Brazil to the production of knowledge and innovations. This dissertation interprets these findings of incipient inter-territorial corridors of tropical knowledge as always mediated through conditions and contingencies of relations. Chapter two begins to lay this governance in a more explicit fashion, the three studies should be interpreted in terms of governance – rather than government - of relations both between multi-locational agents as well as through their interface with actors in home and host regions in which these movers are embedded.

CONTRIBUTIONS AND IMPLICATIONS FOR SCHOLARSHIP

Empirical Contributions

These empirics establish the human geographies of knowledge production that would otherwise be difficult to observe at the level of a subnational or inter-subnational unit due to the absence of established indicators or literature on such processes as part of agro-industries in South America. This dissertation also amalgamated extensive primary sources – both current and historical – from multi-locational agents and their associated relations to establish the relational logics of the social and spatial production of knowledge and innovation. This work triangulated these gleaned insights with typological frameworks from aggregate data in order to elucidate different facets of mobility, absorption and governance of knowledge spill-ins that inter-lock into a

conceptual and causal framework of the effects of the mobility of knowledgeable individuals on the production of knowledge in tropical agricultures. These studies of mobile agents help to lay the basis for more robust explanations of the social mechanisms that move knowledge in tropical agro-industrial systems. These studies form an explanatory framework based on the multi-locationality of agents of innovation that helps to interpret metrics of knowledge and innovation by using new empirics on the mobility of scientists. The research in chapter three also suggests that analysis of citations by knowledge products that contributes a methodological strategy on wider social dimensions of knowledge beyond formal collaborations. This inter-regional matrix conceptualizes the unity between subnational processes and cross-border processes unfold at more global and more localized scales different scales help to extend the literature on subnational innovation in Brazil. These findings contribute to the potential for local studies of particular units of EMBRAPA to integrate activities at more global scales (Penteado Filho and Dias Avila , Penteado Filho and Dias Avila). These findings and framework at the level of extra-regional linkages of regional systems of agricultural innovation and production in Brazil because subnational regions may attain new importance and perhaps differentiation in the current moment of economic change. The literature on production networks across integration between knowledge and scientific communities is barely on the map, as is true for production networks.

Inter-Regional Learning as the Spreading of Technological Change across Socially- and Institutionally-Varied Locales of Knowledge Production

These findings of the multi-locational nature of learning are significant for the current moment due to the way that this may reduce uncertainty on the social, institutional and socio-environmental influences on the directions on wider sets of technological changes in tropical agro-industrial systems. Tying a location such as Brasilia into different places spreads risk wider and may be more resilient than reliance on a single national funder, for example, the national

development bank. These findings contribute new insights to literature on knowledge in agriculture and natural resource-based sectors that analysts suggested but which had not been explored (Bound 2008). This contributes to literature on knowledge in agricultural and other nature resource industries (Figueiredo 2010, 2014). These contribute new perspectives on the role of knowledge flows in shaping development in agro-industries (Wolford 2015).

Implications for the Organization of Agro-Industries in the Tropics

This contributes to literature on the global geography of innovation as part of changes in the structure of agro-industrial production networks at more global scales (Rama and Martinez 2013). This contributes to literature of what is a small literature on the geography of innovation in agro-industries and enviro-sciences in Brazil. These empirical findings and framework provide a lens for understanding and build on and magnify the thicker case study research that demonstrates territory as a source of interactions with multi-locational agribusinesses in South America (Craviotti 2016).These findings contribute to literature that examines the different ways and locations through which multi-locational firms from emerging economies filter territorial factors in other regions (Crescenzi and Rodríguez-Pose 2012, Crescenzi, Pietrobelli, and Rabelotti 2015).

Inter-Regional Knowledge-Based Drivers of Land Use Change in the Tropics

These findings in chapters three and four from the last decade have important implications for the role of distant connections of knowledge understandings of land use change because this era produced reductions in deforestation during the growing of agro-industries and a boom in commodities markets. This is also important because there may be different trends in different regions, which may be linked (Hansen et al. 2013). This contributes empirics on knowledge agents

to a growing literature that seeks to understand indirect drivers of land use change, and the spatial leakage of interventions or economic changes across spatial units. This contributes to literature on distant determinants of land use changes (Meyfroidt et al. 2013). These studies that disaggregated empirics to the level of individual scientists and the branches of subsidiary firms addresses the call of scholars for finer scale data on these land change processes (Godar et al. 2015). South-south telecoupling (Gasparri et al. 2016). Inclusion of distant locations within spatially explicit models of land use change in South America. These findings contribute the literature on land use change on the role of knowledge in telecoupling and teleconnections of land use change between different regions (Gasparri et al. 2016). This framework that addresses the spillovers of knowledge contributes to literature that suggest that includes the potential for the role of know-how, practices and experience (Gasparri et al. 2016). These frameworks developed in these contribute to literature in land use that seeks to develop and test framework on spatial linkages between distant regions and their effects of land use change (Liu et al. 2014, Liu et al. 2015). The findings of the mobility of firms in chapter four contributes new empirics on land use literature that seeks to understand the siting decisions of multi-locational firms as part of land use changes in South America (le Polain de Waroux et al. 2016). The framework and initial findings in chapter three suggest that there is an attractive feature of diverse institutional contexts in ways that suggest that parallels between regions should not be taken at face value (Gasparri et al. 2016). This matrix framework contributes to literature that recognizes that knowledge and institutions are linkages between producer regions in developing countries that affect land use change, although these are poorly-understood and less-examined in comparison to material flows between regions (Gasparri et al. 2016). These papers contribute to a broader conceptualization of the role of mobile human agents in facilitating a wider number of social remittances that shape changes in land use associated with agro-industries (Hecht and Saatchi 2007, Hecht et al. 2015). Complexity of land use is associated with knowledge and not just human impacts. These represent social remittances of knowledge. These findings contribute empirics to the call for more actor-centered approaches in order to understand the multi-scalar processes that shape land use

change (Gasparri and le Polain de Waroux 2014). These finding respond to the call for more actor-centered approaches to land use change by examining the knowledge flows that these represent (Gasparri and le Polain de Waroux 2014).

Governance of Mobile Geographies of Innovation

These social relations are building blocks to an understanding of institutional formation across these territorial channels. These three studies present insights into spatially- and organizationally-decentered territorial dynamics of innovation that may develop as an unintended side effect or complement of processes presented in more centralized explanation of a Brazilian model of development or industrial policy. These sectoral findings on public and private multi-locational agents in agro-industries contribute to scholarly literature that seeks to explain the public and private sector logics of mobility from Brazil (Yumi Ramos and Velho 2011). This dissertation that focuses on the mobility and tropical agro-industrial systems contributes to wider debates over the governance of geographies of innovation over the last decade. The question of innovation has not been well-enough untangled from the explanations of the developmental state nor within the reckoning and struggles in the political economy of the former Workers Party of Brazil between 2003 and 2016 (Almeida and Schneider 2012). The networked structure of the inter-regional learning matrix in agro-industries also may contribute a sectoral perspective that demonstrates a separate dimension beyond the small networks of ties that leading scholars of capitalism in Brazil (Lazzarini 2011).

FUTURE RESEARCH ON TROPICAL MOBILITIES AND THE MATRIX

This dissertation provides empirical foundations, conceptual frameworks and hypotheses for future research on the inter-regional geography of agro-innovation in the tropics. The collective set of aggregate empirics on key multi-locational agents developed by these studies provides a rich source of evidence for statistical explanations as well as for selection of cases for thicker qualitative case study research. The conceptual framework that organizes the three studies provides a guide to research on the multi-locational processes of other innovative agents on which there is little or no scholarship, including co-operatives, rural unions, business associations, environmental networks.

Learning and Innovation by Individuals in, and Across, Branches of Subsidiary Firms

The findings in chapter four paves the way for additional research to confirm what chapter four suggests geographies of learning from spillovers from territorial factors that that shape innovation by branch locations that shape flows of knowledge across the borders into home regions in Brazil. Qualitative analysis with individuals within these organizational setting of subsidiary branch locations in Latin America, as well as across channels to subnational regions within Brazil or elsewhere can assess the way that these serve as a source of learning to locations in subnational regions within Brazil. An investigation of patents held by firms that move across the borders is also a starting point for research.

Knowledgeable Individuals as Multi-Locational Agents of Innovation in the Tropics

Future research should address a wider set of heterogeneous agents of innovation beyond the public research scientists and large agro-industrial firms. This includes firms from other sectors and size classes. It also includes civil society organizations. Environmental organizations, small and medium producer cooperatives and organizations, and civil society organizations concerned with the governance of land and land use also shape technological trajectories and also interact with agents across borders. Additional research is required on the different types of knowledge systems that these express.

Governance between Multiple Agents

A key area for future research is on the relations of governance of learning between different multi-locational agents for the EMBRAPA scientists and agro-industrial branches studied in chapters three and four, as well as other agents of innovation outside of the scope of the present dissertation. Additional research on small producers, business associations, indigenous knowledge systems, global conservation networks, firms in other sectors, and other agents from regions in Brazil and other locations. The most pressing need is for additional research on the critical dimension of how multi-locational agents interact with other mobile and more localized agents in their home regions. This requires more research into the way that knowledge from other locations is shared by multi-locational agents in their home region. This research contributes empirics that lay the basis for additional research to examine the nature of relationships between different multi-locational agents from a particular location in Brazil or, in a particular location in Latin America and the way that this is related to place. There is also a need for research into how these agents interact outside of their home region.

Spatial and Statistical Analysis of Effects of Mobility on Regional Outcomes of Knowledge

The new datasets on the activities of firms and EMBRAPA in chapter three establish a novel set of empirics through which to conduct a spatially-explicit statistical analysis of the relationship between mobility as a source of knowledge spillins at a global level through the EMBRAPA case. This requires an investigation into citations. This can also examine the networks structure.

IMPLICATIONS FOR POLICIES AND PRACTICES

Governance of EMBRAPA Scientists Abroad

These findings have implications for policy debates within EMBRAPA over the activities and geographies that fit the logics of innovation of the organizations. mobility in relationship to virtual relationships, both in Latin America but also more generally in Labex. On the one hand, indicators suggest that there are risks of dispersion of EMBRAPA activities abroad (EMBRAPA 2015). On the other hand, the frameworks of forecasting opportunities on uncertainty suggest the broader search networks (Torres, Kanadani Campos, and G. 2013). This suggests the importance of widening the spatial and scope of explanations of the cross-border activities of EMBRAPA as an organization that seeks to organize innovative activities in space in new ways into the future (EMBRAPA 2013). These findings from a leading set of public sector tropical scientists also presents insight for other policy analysts that are seeking to explain the lessons that the global linkages of the systems of innovation in Brazil provide for other public interventions in agricultural innovation in different contexts in Latin America as well as Africa (Correa and Schmidt 2014). These findings also provide frameworks for a range of small producer groups and environmental

networks concerned with agriculture as well as land use effects of agriculture that also form part of the multi-locational governance of such tropical channels. These findings contribute to a policy debate over diffusion versus specialization within the global activities of EMBRAPA, which develops within a new context of politics and budgetary restraints on EMBRAPA in the current moment.

Governance of Scientific Mobilities as Innovation

These findings contribute to a wider debate over the policy interventions as part of the governance of the mobility of scientists from Brazil in light of the ambitious policy experiment surrounding the Brazilian Scientific Mobility program . A recent casualty of budget cuts in 2014 was perhaps the most ambitious policy initiatives with respect to innovation by the Brazilian government that sent nearly 100,000 graduate students and researchers in agro- and enviro-sciences and other so-called STEM fields of the so-called STEM fields of science, technology, engineering and mathematics that engaged in mobility at global scales with the support of the Scientific Mobility program of the Brazilian government. This represented a four-fold increase of support for foreign study in addition to policy changes that focused on a broader range of concerns in science and applied activities beyond purely academic concerns. 3,197 in sustainable agricultural production, in addition to 41,594 in engineering, 7,361 in physical and land sciences, 2039 in biotechnology and 1,000 in renewable energy . However, there has been limited study of the goals and outcomes of these processes and debates have emerged over these policies (Castro et al. 2012). The challenges of governance include the top-down role of the program beginning from the presidency, in addition to question around the ability of ministries of education to interact with the private sector in a program that has sought to incorporate technical and not merely academic concerns (Castro et al. 2012). These finding from plant scientists have implications that suggest the importance of addressing the significance of these processes for

more varied sets of outcomes. The findings of this study suggest the importance of locating this in a longer trajectory of learning. This included firms that would be involved in mobility. The findings of this dissertation provide a subnational perspective of cross border mobility in terms of destinations, as existing metrics are organized in terms of destinations at the level of the nation-state.

Filtering Knowledge through New Locations of Inter-Regional Channels

The inter-regional "channels" of the present approach to the matrix also contribute to discussions over proposed interventions by Brazil's leading business association to establish "corridors" between locations in Brazil and the United States as part of the 'densification" of an entrepreneurial scientific base for Brazil's "bio-economy" (HBR and CNI 2013, 16). The inter-regional channels framework of the present dissertation suggests that the organizational basis of such calls also consider the territorial context, both of which centers of excellence develop, but also in areas where is not center of excellence. In some ways, this proposal extends discussion of the triple helix of interactions in Brazil to global scales. also consider a wider set of territorial factors beyond the organizational focus on centers of excellence. The findings of the matrix approach also suggest the need for attention to the plural matrix of channels that expands the locations that shape the initiatives of private sector actors in the "bio-economy" from Brazil that seek to establish "corridors" of innovation to locations in the United States

The close of the recent chapter of growth in Brazil and other emerging economies is also an opening to the rediscovery of hidden places of resilience in economic and ecological systems into the future. The statement that the governance of innovation increasingly drives economic shifts is well-trodden. However, the dynamics through which knowledge manifests spatially in sectors and territories connected to natural resources in the emerging economies has remained,

by comparison, largely unexplored. This dissertation began from the vantage of global hotspots of "tropical knowledge" within Brazil, and "mobilizes" a new set of empirical and conceptual tools that bring the inter-regional prism of these places into better focus. A growing body of historical work has unearthed traveling crops whose global circulation remade both old and new worlds throughout time. The present dissertation sees into the future by re-discovering the mobilities of "local" agents from tropical regions whose spectrum of social knowledge moves the crux of new geographies across an uncertain moment of technological and climatic change.

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