Rural Sociology ••(••), 2010, pp. ••–••

Global Economic Integration and Local Community Resilience: Road Paving and Rural Demographic Change in the Southwestern Amazon*

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Abstract. Recent years have witnessed an expansion in international investment in large-scale infrastructure projects with the goal of achieving global economic integration. We focus on one such project, the Inter-Oceanic Highway in the "MAP" region, a trinational frontier where Bolivia, Brazil, and Peru meet in the southwestern Amazon. We adopt a resilience approach as an integrative framework to understand various types of road-paving impacts. We focus on migration activity as an indicator of retention of collective memory, a concept associated with resilience. We pursue a comparative analysis of the three sides of the MAP frontier as well as subregions within each side. Since road paving may be mediated by other factors, we distinguish among the effects of multiple explanatory factors. Data come from a multinational survey

* Financial support for this research came from the National Science Foundation, Human and Social Dynamics Program, Grant #0527511, and from the U.S. Agency for International Development, Latin America and Caribbean Program in Environment, Cooperative Agreements RLA-A-00–06–00071–00 and 512-A-00–08–00003–00. We are coordinators of the socioeconomic component of the NSF grant and thank the students and other collaborators who contributed to the community-survey fieldwork and data entry in Madre de Dios, Peru (Angélica Almeyda, Mercedes Perales Yabar, Wendy Cueva Cueto, Rosmery Chacacanta Niño de Guzman, Eder Nicanor Chulla Pfuro, Boris Arguedas, Yeni Franco Solano, Erika Quispe Ruiz, Andrea Chávez, Rosa Cossío, Rafael Rojas); Acre, Brazil (Adão Costa Silva, Jeff Hoelle, Karla Rocha, Jesus Melo, Vera Gurgel); and Pando, Bolivia (Ioav Rojas Camacho, Israel Puerta, Kelly Biedenweg, Dave Elliott, Alexander Shenkin). For logistical support we thank Veronica Passos, Bertha Ikeda, and Daniel Rojas. For helpful suggestions we thank Julio Rojas, Frank P. de la Barra, Amy Duchelle, Valerio Gomes, and Jackie Vadjunec.

of rural communities. The findings show considerable net migration and turnover, both indicative of eroding collective memory and a lack of demographic resilience to externally induced change in the MAP frontier. The findings indicate variation across the frontier, which road paving helps explain, along with some of the mediating factors. These findings contribute to the literature on the impacts of new infrastructure and integration as well as the study of social-ecological resilience.

Introduction

The first years of the new millennium have witnessed important shifts in the initiatives put forward to realize global economic integration, particularly those seeking to incorporate rural areas and developing regions. During the 1990s, many world regions including the Americas pursued neoliberal policies including free trade agreements (Carranza 2002; Pastor 2004). However, uneven economic performance, popular protest of closed-door economic summits, and gridlock among negotiators over initiatives such as the Free Trade Area of the Americas have hampered such efforts (Kellogg 2007; Wainright and Ortiz 2006).

At the same time, other integration initiatives have proceeded, notably infrastructure projects to facilitate access to natural resources in heretofore peripheral areas and to foster distribution of production via continent-wide transportation networks (Bourguignon and Pleskovic 2008; Cáceres Zapata 2001). In Latin America, the Initiative for Integration of Regional Infrastructure in South America (IIRSA) was constituted in 2000 by the presidents of several countries to coordinate infrastructure projects along roughly a dozen axes of integration (Tizón and Gadea Duarte 2002; Iniciativa para la Integracion [IIRSA] 2008). Such initiatives have in turn drawn critical attention, given the politically contentious impacts of previous high-profile infrastructure projects in developing regions such as the Amazon (e.g., Alencar et al. 2004; Dourojeanni 2006; Killeen 2007).

Infrastructure upgrades can generate positive and negative sociopolitical, economic, and ecological impacts, which have prompted scholars to seek integrative approaches to their study. We therefore adopt a resilience approach, and evaluate resilience to road paving among rural communities. For analytical tractability, we focus on demographic changes, as the literature on demographic impacts of roads is relatively small. We focus on a trinational frontier region in South America, the site of a major infrastructure project that comprises one IIRSA axis of integration. We draw on a community-level survey and pursue a comparative analysis of demographic changes in adjacent areas with and without road paving. The analysis features migration indicators, which

we interpret in light of resilience thinking. The comparisons provide support for road paving as well as some of the mediating factors in accounting for variation in migration across the trinational frontier. The findings also indicate substantial migratory activity and thus raise doubts about the demographic resilience of rural communities in relation to road paving.

Background

Road Impacts

There are several rapidly growing literatures on road impacts. One key literature concerns the ecological impacts, whether via landscape fragmentation, which yields consequences such as biodiversity loss and biomass collapse, or via hydrological changes involving road runoff of chemical pollutants and stream sedimentation that undermine watershed integrity (e.g., Coffin 2007; Forman et al. 2003). In contrast to the emphasis on negative impacts in the ecological literature, treatment of transportation infrastructure by economists has been more positive. The relevant economics literature highlights support for arguments that infrastructure improvements are instrumental for economic growth (e.g., Bourguignon and Pleskovic 2008; Straub 2008) as well as rural poverty alleviation (e.g., Fan, Zhang, and Zhang 2004; van de Walle 2002).

Beyond the ecological and economic literatures is a more diffuse, fragmentary body of work on various sociopolitical impacts of new infrastructure, including damage to archaeological sites, forced resettlement, and unequal access to amenities. We focus on the literature on infrastructure upgrades and local demographic change, which is relatively small (Chi, Voss, and Deller 2006). Earlier studies of highways and population change by sociologists in the United States suggested positive effects on growth rates at the county level (e.g., Humphrey 1980; Humphrey and Sell 1975; Lichter and Fuguitt 1980). Such work highlights the links between economic and demographic changes in response to infrastructure. The economic-demographic link features migration in response to improved access to employment and urban amenities. The literature on roads and population also emphasizes indirect causation from roads via intervening factors such as economic change to understand demographic changes. More recent work on the United States links highway expansion to economic and structural changes that then afford interpretation of demographic outcomes (Chi et al. 2006; Voss and Chi 2006). Such work goes beyond the macroeconomic literature by emphasizing distinct changes among rural, suburban, and urban areas, and between the preconstruction, construction, and postconstruction

phases of infrastructure upgrades. For rural areas, the prevalent argument has been that population grows during all three phases due to business investments and the consequent employment opportunities and increased amenities, which result in in-migration and perhaps suburbanization.

Conclusions about infrastructure in rural areas are more varied from the literature on developing countries. Key to the effect of roads on rural population change in developing areas is whether infrastructure creates opportunities for rural communities, which attract population, or only provides access to cities, which often induces rural-urban migration. In some instances, road paving generates population growth in rural areas as local peoples diversify their livelihood activities by adding market-oriented artisanal production sold in towns to their preexisting farming and extractive activities (Rudel and Richards 1990). Similarly, if roads provide access to urban amenities without harming rural enterprise, rural population may grow. But infrastructure upgrades may yield other outcomes, including stagnation of population, such as that due to consolidation of landholdings (Trankell 1999). Benefits may accrue only to limited areas, resulting in different outcomes in rural regions where highway corridors exhibit dynamism but accessibility elsewhere is not improved, yielding stagnation in more remote locations (Mahapa and Mashiri 2001). Similarly, rural stagnation in population may occur despite considerable geographic mobility if migration occurs between urban areas, effectively passing over rural interstices. Finally, if roads reinforce or sustain rural-urban wage differentials, they may draw rural populations from the countryside and into cities (Issah, Khan, and Sasaki 2005).

Roads in the Amazon

In our study region, Amazonia, there have been many infrastructure projects that generated demographic changes of diverse types. One of the earliest such projects was the Belém-Brasília Highway, a north-south corridor in the eastern Brazilian Amazon, which in the 1960s generated land conflicts and rural depopulation as communities in the road corridor were evicted by investors forming large-scale cattle ranches (Branford and Glock 1985). Perhaps the most famous of the Amazon infrastructure projects was the Transamazon Highway, an east-west corridor that linked Brazil's impoverished Northeast to the central Amazon, viewed by military planners as a demographic vacuum (Moran 1981; Smith 1982). Construction of the Transamazon in the 1970s was paired with an ambitious colonization program, which attracted many more

migrants than Instituto Nacional de Colonização e Reforma Agraria (INCRA), the state colonization agency, could handle. But when the economic crisis of the early 1980s hit, state spending cuts meant withdrawal of support for colonization, and demographic expansion slowed. The best example of a road yielding rapid population growth in the Amazon is the BR-364 Highway from southern Brazil into the state of Rondônia, where the population grew from roughly 100,000 in 1970 to nearly 500,000 by 1980 and over 1 million around 1990 (Browder and Godfrey 1997). This occurred for a variety of reasons, but a prominent factor was the consolidation of high-value land in southern Brazil into large mechanized export-oriented operations at a time when BR-364 connected the south to much cheaper land in the Amazon. This prompted many southern farm families without capital for mechanization to sell out and migrate to the Rondônian frontier where they could acquire larger properties.

By attracting migrants, infrastructure projects in the Amazon generated land and resource conflicts with indigenous groups, forest extractivists, and other preexisting rural communities (Davis 1977; Hemming 2002; Leonel 1992). The tumultuous alterations along roads in frontier areas of the Amazon since the 1960s resulted in an array of new spaces of occupation in which long-standing rural communities were complemented by new colonies and towns (Browder and Godfrey 1997; Hemming 1985; Schmink and Wood 1992). The constitution of new rural communities was often a contentious process, especially since frontier settlements were organized around access to land, itself a highly political issue (Schmink and Wood 1992; Simmons et al. 2007). Rural violence and land consolidation pushed many migrant families out of the countryside, yielding growing urban populations in regional cities (Becker 1995; Browder and Godfrey 1997). Rural and urban communities have since proliferated in the Amazon, and exhibit diverse local trajectories among different spaces of occupation (Nascimento and Drummond 2003; Toni and Kaimowitz 2003). Frontier expansion and contestation over natural resources stimulated social mobilization in many places of the Amazon, especially among rural communities, who have engaged in various strategies to defend their land claims and livelihoods (Hall 1997; Kainer et al. 2003; Simmons et al. 2007).

It is in this historical context that a new generation of infrastructure initiatives is being implemented in the Amazon under IIRSA. Such initiatives have incurred criticism, primarily concerning the ecological impacts, as simulation models of road corridors in the Amazon project expanding forest degradation and clearing (Soares-Filho et al. 2004). This raises questions about the prospective social impacts, particularly

on rural communities (Alencar et al. 2004; Mendoza et al. 2007), including the whether communities will survive via retention of population or experience disruption via population change.

Interpretive Approach: Resilience

We address this question by adopting a resilience approach to interpretation. Specifically, we examine the ramifications of road paving in the Amazon for rural community resilience in terms of migration indicators. We recognize that there are alternative approaches to the study of road paving and demographic dynamics. We adopt a resilience approach because our effort here is part of a broader, integrative analysis of infrastructure change and the consequent social and ecological dynamics. We view demographic dynamics as a link between social and ecological changes because rural communities in the Amazon are directly dependent on natural resources for their livelihoods, which can affect household migration decisions and family welfare.

The notion of resilience originated in systems ecology (Holling 1973). Resilience has been variously defined as the capacity of complex systems to exhibit stability or persistence in the face of change, to adapt creatively to externally induced shocks, or to exhibit self-organization. Resilience thinking has more recently been applied in discussions of social as well as ecological change (Gunderson, Holling, and Light 1995). That in turn prompted consideration of "social resilience" as the capacity of social groups or communities to withstand or adapt creatively to externally induced shocks (Adger 2000; Adger et al. 2005).

Conceptual discussions of resilience have proceeded alongside struggles to design measures of resilience (Carpenter et al. 2001). We draw on one such effort, which formulates resilience in terms of the components and their relationships in a system, and how they change or persist (Cumming et al. 2005). This formulation allows consideration of components and their relationships as they may influence alterations or allow continuity in the system, providing a basis for evaluating system resilience. For our purposes, we focus on rural communities as our system components, highlight the relationship of road paving to community demographic dynamics, and feature questions of whether communities exhibit demographic persistence or change.

We feature the concept of "memory" in linking resilience thought to our demographic analysis. In the resilience literature, *memory* refers to the ability of a system to retain fundamental properties, and is viewed as crucial for system recovery following a shock (Adger et al. 2005; Berkes and Turner 2006; Folke, Colding, and Berkes 2003; Walker and Salt

2006). While communities constitute system components on a regional scale, we also view communities as local aggregates with their own system properties (i.e., components and relationships). We therefore focus on the retention of collective memory as a key hallmark of community resilience. As local aggregations of families, communities exhibit social organization via procedures to elect representatives who reproduce local institutions via practices that internally adjudicate disputes among community members. Over time, practices of managing natural resources and resolving conflicts constitute collective memory that enable community production and reproduction and thus local social-ecological resilience. To the extent that collective memory is lost, respect for such practices is undermined, threatening the viability of community organization.

For rural communities, we employ demographic measures of population change via migration to evaluate the retention of collective memory (cf. Adger 2000). Regions experiencing infrastructure change often incur rapid population growth and turnover, as in past frontier areas of the Amazon (Schmink and Wood 1992). A key consequence is that traditional resource-management practices are replaced with destructive alternatives (Serrão and Homma 1993) and communities experience disruptions and conflicts from which they have difficulty recovering.

We operationalize demographic resilience at the community level in terms of migration. Specifically, we focus on net migration (i.e., in-minus out-migration) and population turnover (i.e., in- plus out-migration). This follows the lead of previous work on highways and population change (Chi et al. 2006) and roadside community change in the Amazon (Schmink and Wood 1992).

We deploy resilience thinking as an interpretive approach to understand community-level migration indicators in light of externally induced change involving road paving. Smaller values for net migration and turnover imply less rapid community reorganization, which is easier to manage due to retention of a greater modicum of collective memory. Thus, slower demographic change is indicative of greater community resilience. On the other hand, we view large values for net migration and turnover as indicators of community vulnerability. Both suggest alterations in community populations that undermine continuity via erosion of collective memory, and thus reduce capacity for organized response to rapid change in the future.

Study Case

Our study region is a trinational frontier in the southwestern Amazon where Bolivia, Brazil, and Peru meet. Called the "MAP" region, after the

states that form the area (**M**adre de Dios, Peru; **A**cre, Brazil; **P**ando, Bolivia), it is an area of humid tropical forest of exceptionally high biological diversity (Myers et al. 2000). MAP is also a region of substantial social diversity, for it includes indigenous peoples and traditional forest extractivists, as well as recent arrivals including colonists, ranchers, and miners, along with growing urban populations (Iniciativa MAP 2008).

The MAP frontier is also the heart of the Brazil-Bolivia-Peru axis of integration in South America (Tizón and Gadea Duarte 2002; IIRSA 2008). The centerpiece of this axis is the Inter-Oceanic Highway, which links Atlantic ports in southern Brazil to Pacific ports in Peru. The last unpaved segments of the Inter-Oceanic Highway are in the MAP frontier, making it a strategically important region for global economic integration via road paving.

Road paving differs across the three sides of the MAP frontier. The Inter-Oceanic Highway was paved on the Brazilian side in the state of Acre up to the Peruvian border by the end of 2002; paving is now under way in Madre de Dios; and key road corridors in Pando remain largely unpaved, though the Bolivian government recently announced plans for upgrades. MAP thus affords a simultaneous comparative analysis of demographic dynamics before, during, and after road paving.

Explanatory Framework

Based on one recent framework for the demographic impacts of highways (Chi et al. 2006), we should anticipate pronounced migratory activity in rural communities before, during, and after paving. There are other reasons to suppose this might be the case among rural communities across the MAP frontier. Some analysts have highlighted "spillover" effects from one place to another in the presence of new infrastructure, which can diminish local differences in economic-demographic changes (Boarnet 1998).

That said, it is likely that community migration dynamics will differ across the MAP frontier. Madre de Dios, Acre, and Pando are located in different countries, which has the potential to differentiate them, even among rural communities in the same region. Assuming there are differences among rural communities across the MAP frontier, we do not expect a simple, linear relationship between road paving and demographic dynamics. Past experiences in the Amazon have varied, and there are reasons to expect communities with paving to have greater as well as less migratory activity.

We suggest that divergent outcomes can potentially be explained by several explanatory factors that mediate the relationship of road paving and community migratory activity (cf. Chi et al. 2006). Because our

Table 1. Expectations Regarding Road Paving and Mediating Factors for Community Migration Dynamics and Resilience, Trinational MAP Frontier, Southwestern Amazonia, Bolivia, Brazil, and Peru

Explanatory Factor	Madre de Dios	Acre	Pando
Road paving	Medium (0)	High (+1)	Low (−1)
Land-tenure consolidation	Medium (0)	High (−1)	Low (+1)
Rural economic dynamism	High (+1)	Low (−1)	Medium (0)
Rural, urban populations	Medium (0)	Large (+1)	Small (−1)
Population growth rate	Medium (0)	Low (−1)	High (+1)
Community migration intensity	High (+1)	Low (−1)	Medium (0)

analysis features comparisons, we pursue "individualizing comparisons" (cf. Skocpol 1984; Tilly 1984) of the mediating factors across the three sides of the MAP frontier. We employ individualizing comparisons in order to theoretically distinguish the implications of the mediating factors for community migration dynamics. This approach improves our chances of separating their effects among a handful of comparison cases. Because our focal outcome (migration) is quantitative rather than qualitative, our evaluation involves relative values rather than nominal differences.

Table 1 provides an outline of these factors and our expectations. Each factor, beginning with road paving itself, differs across the MAP frontier and theoretically bears implications for community migration dynamics. In Table 1 we make comparisons of the relative levels for each factor across the three sides of the MAP frontier (i.e., high-medium-low). We also provide (in parentheses) an indication of the anticipated effect on the relative intensity of migration (+1 for increased, 0 for neutral, −1 for decreased).

In addition to road paving, we consider the following mediating factors: land-tenure consolidation, rural economic dynamism, and state rural and urban population sizes and growth rates.[1] By itself, road paving

[1] We could consider other factors, particularly characteristics of rural communities themselves, such as level of development, governance structure, or support from outside organizations. Table 1 emphasizes factors external to rural communities, operating on a similar level to that of road paving. This better fits our resilience framework, which emphasizes community response to externally induced change and allows for more direct evaluation of road paving as compared to the mediating factors. We nonetheless regard conclusions from Table 1 as illustrative rather than definitive, though our interpretation would not change from the one we provide had we added more factors, because our point is to argue that migration activity is likely to differ across the MAP frontier in ways that differ from the expectations we would have if only road paving were operating. Elsewhere we pursue multivariate analysis at the community level to incorporate the effects of community-level factors; here we focus on comparisons among geographic clusters of communities.

should accelerate migration intensity and thereby undermine community resilience because paved highways facilitate access not only to natural resources, attracting population and fostering expanded economic activity, but also to urban markets where the products of such activity can be commercialized. This is the pretension of every IIRSA project as well as all previous infrastructure projects in the Amazon: integration for economic and demographic growth. Since the Inter-Oceanic Highway was at the time of our research paved in Acre, we should expect greater migratory activity there; with the highway under construction in Madre de Dios, we should anticipate somewhat less migration there; and given the relative lack of paving in Pando, we expect relatively low migration there. That said, this may not correspond to the overall picture across the MAP region, because mediating factors may modify the migration differential due to road paving.

Land/resource-tenure consolidation is a case in point. More consolidated tenure regimes afford more security for landholders, which can buffer against external shocks and offer stability to rural populations and production systems (Alston, Libecap, and Mueller 1999). The situation in Acre is more consolidated, with a large proportion of the land area having been demarcated and given specific rules for access and use (Governo do Estado do Acre 2006). By contrast, in Madre de Dios and Pando, there is more land available and not yet demarcated by the state, and established communities have recently gone through the process of "saneamiento" or clarification of ownership and property boundaries. On this basis, we expect less migratory activity in Acre than in Madre de Dios or Pando. Thus, tenure consolidation may dampen the effects of road paving since the two should have opposing effects on migration.

Rural economic dynamism is another mediating factor likely to affect migration. In recent years, the economic fortunes of rural communities across the MAP region have fluctuated. In Madre de Dios, gold mining has expanded, constituting a major source of income. Across the MAP region, but especially in Pando, high prices for castaña ("Brazil nut") increased rural community incomes. In Acre, the consolidated tenure system includes rules limiting deforestation, which now constrains rural livelihood options because most rural families and communities lack the assets to intensify their production via agricultural mechanization. In sum, economic dynamism appears greatest in Madre de Dios, followed by Pando, trailed by Acre, which suggests greater migratory activity in the first of these.

This leaves state-level rural and urban population sizes and growth rates. To observe these, we drew on rural and urban population counts for all demographic censuses in Bolivia, Brazil, and Peru dating back to

roughly 1980 (Instituto Brasileiro de Geografia e Estatística [IBGE] 2008; Instituto Nacional de Estadística [INE] 2008; Instituto Nacional de Estadística e Informática [INEI] 2008). This practice allows observation of rural and urban growth over at least two intercensal intervals.

Table 2 presents the rural and urban population figures and exponential growth rates for Madre de Dios, Acre, and Pando from roughly 1980 to the last available census. In terms of rural and urban population sizes, Acre has the largest, followed by Madre de Dios and then Pando. This indicates larger available populations for migration in Acre, which could result in greater migration activity there. Regarding the growth rates, in all three sides, urban growth exceeds rural growth, but important differentials appear among sides, with higher urban and rural growth rates in Pando, followed by Madre de Dios and then Acre. Consequently, there may in fact be less potential for migratory activity among communities in Acre than elsewhere.

At the bottom of Table 1 we provide a summation of the expected migration intensity. As a simple exercise, we sum up the expected effects on migration intensity across the explanatory factors for each side of the trinational frontier. This exercise assumes that the importance of each factor is equal and that the effects are additive. We do not regard these assumptions as entirely accurate, but they serve as a point of departure in forming our expectations for comparisons of migration activity across the MAP frontier, especially since we anticipate rather different effects for each explanatory factor. Overall, Table 1 suggests that migration intensity will be highest in Madre de Dios (due to high economic dynamism and medium values for the other factors), moderate in Pando (due to a high population growth rate and low tenure consolidation, offset by other factors), and lower in Acre (due to completed road paving and a large population, offset by other factors).

Four theoretical observations arise from Table 1. First, our expectations about migration activity based only on road paving differ from a broader appraisal incorporating mediating factors. This observation still holds if we relax our assumption about the equal and additive importance of the explanatory factors (unless one were to assume that road paving was of overwhelming importance). Second, our expectations about community resilience based on road paving do not correspond to our overall expectations, which implies that road paving by itself does not necessarily undermine community resilience if there are offsetting factors at work. In other words, communities incurring road paving may not turn out to be less resilient. Third, Table 1 compares only the three sides of the frontier, each of which contains heterogeneous subregions. For example, within a given side, some communities

Table 2. Rural and Urban Population Growth in the MAP Frontier (Madre de Dios, Peru; Acre, Brazil; and Pando, Bolivia), 1976–2007

Population	Time 1	Time 2	Time 3	Time 4	Growth Rate 1	Growth Rate 2	Growth Rate 3
Madre de Dios, Peru	1981	1993	N/A	2007	1981–93	N/A	1993–2007
Total	33,007	67,008	N/A	109,555	5.90	N/A	3.51
Rural	17,047	28,575	N/A	29,246	4.30	N/A	0.17
Urban	15,960	38,433	N/A	80,309	7.32	N/A	5.26
Percentage urban	48.4	57.4	N/A	73.3			
Acre, Brazil	1980	1991	2000	2007	1980–91	1991–2000	2000–2007
Total	301,276	417,098	557,526	655,385	2.96	3.22	2.31
Rural	169,346	158,230	187,259	190,705	–0.62	1.87	0.26
Urban	131,930	258,869	370,267	464,680	6.13	3.98	3.24
Percentage urban	43.8	62.1	66.4	70.9			
Pando, Bolivia	1976	1992	2001	N/A	1976–92	1992–2001	N/A
Total	34,493	38,072	52,525	N/A	0.62	3.58	N/A
Rural	30,843	28,071	31,705	N/A	–0.59	1.35	N/A
Urban	3,650	10,001	20,820	N/A	6.30	8.15	N/A
Percentage urban	10.6	26.3	39.6	N/A			

Sources: IBGE 2008, INE 2008, INEI 2008.

are closer to the state capital. Less distant communities are more likely to engage in daily rural-urban circulation and thus exhibit rural population retention, whereas those farther away could be more subject to permanent rural-urban migration in the event of road paving. Further, in the case of Madre de Dios, some communities have paving while others do not, which is also likely to differentiate communities. And fourth, the fact that we anticipate different effects of different explanatory factors on migration, along with making multiple comparisons across and within the three sides of the MAP frontier, means there are multiple opportunities to distinguish among explanations for variation in migration. While we have overall expectations about variation in migration, we also have specific expectations for each explanatory factor. This informs our explanatory strategy, such that we can explain a given pattern of differences in migration across comparison cases in terms of the explanatory factor(s) that fit the pattern. We attend to these issues in our analysis.

Methods

We draw on a multinational survey of rural communities along the Inter-Oceanic Highway and other key roads in the MAP frontier. This survey is part of the socioeconomic component of a larger project seeking to evaluate the ramifications of changes in highway infrastructure and regional connectivity for social-ecological resilience. The community survey encompasses the first phase of our socioeconomic fieldwork, in which we sought to gather comparable data for rural communities on all three sides of the MAP frontier.

With secondary data, we identified communities in a Geographic Information System (GIS) as distinct land-tenure units or population centers along major roads in the MAP frontier. We focused on the Inter-Oceanic Highway in Acre and Madre de Dios, as well as primary roads in Pando near borders with Brazil and Peru. We then sampled communities at varying distances from their respective state capitals along primary roads. In Madre de Dios and Pando, rural communities have nucleated population centers on or near primary roads; in Acre this is less often the case. Figure 1 shows the spatial distribution of the communities selected.

In 2007, faculty and students from the University of Florida served in a collaborative fashion on field teams with counterparts from the National Amazonian University of Madre de Dios for fieldwork in Madre de Dios and with counterparts from the Amazonian University of Pando for fieldwork in Pando. In 2008, UF and counterpart faculty and students

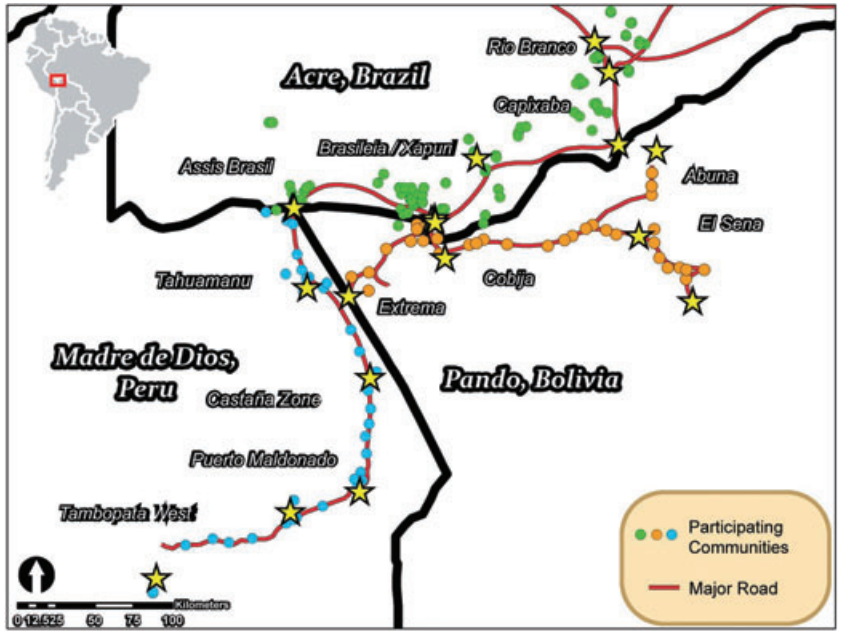

Figure 1. Geographic distribution of interviews with leaders of rural communities in the MAP frontier (Madre de Dios, Peru; Acre, Brazil; and Pando, Bolivia). Stars indicate local market towns.

at the Federal University of Acre collaborated on fieldwork in Acre. In the selected communities, we identified one or more community "leaders" (i.e., current or past association presidents, longtime residents, local teachers, and other knowledgeable informants). In Madre de Dios, we visited 41 community associations and conducted 88 interviews; in Acre, we visited 25 distinct land-tenure areas (with roughly 50 community associations and cooperatives) and conducted 93 interviews; and in Pando, we visited 37 communal land areas, where we conducted 111 interviews.[2]

We employed a structured questionnaire with open-ended questions to obtain comparable information and yet allow respondents to elaborate on

[2] For our purposes, "community" refers to an aggregation of families in a given location. Specific definitions of communities vary across the MAP frontier because rural land tenure varies, both among and within countries. In Pando, communities refer to communal land-tenure units ("predios") consisting of nucleated settlements where member families use the surrounding lands. In Madre de Dios, communities are constituted in local farmer associations consisting of member families with private individual land parcels. In Acre, communities vary in definition because land-tenure arrangements are diverse, such that a community may refer to families residing in various types of state-designated land-tenure

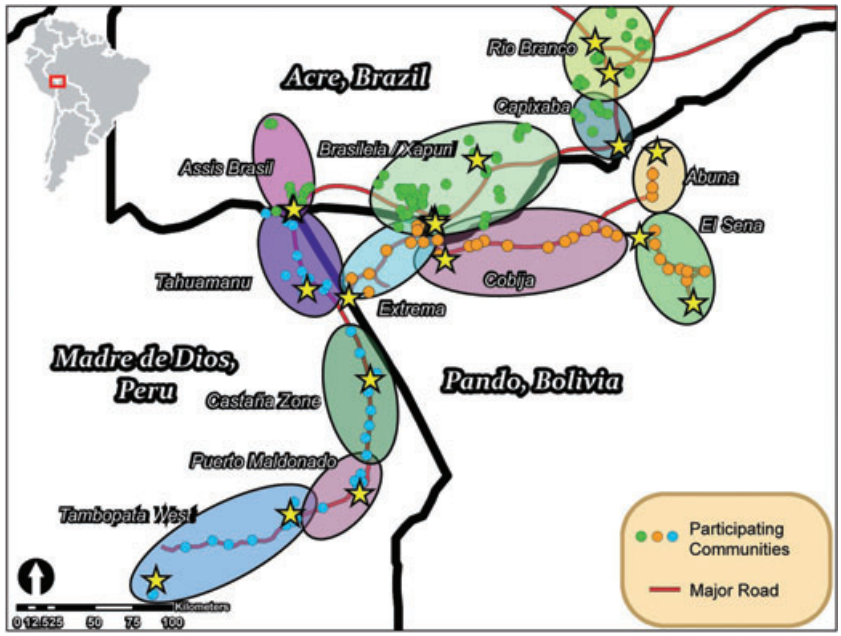

Figure 2. Subregions within sides of the MAP frontier (Madre de Dios, Peru; Acre, Brazil; and Pando, Bolivia). Stars indicate local market towns.

their responses. The questionnaire included items on demographic topics including community population size and migration (families that joined in the past five years, families that left in the past five years). These data allow for comparisons of migration intensity in rural communities in places that differ in terms of road paving and mediating factors.

For a more refined analysis that allows a greater set of comparisons to better sort out explanations for migration differentials, we distinguished among four subregions within each of the three sides of the MAP frontier, shown in Figure 2. Our distinctions are based primarily on distance to state capitals, but they also reflect other locally varying factors, such as availability of natural resources tied to dynamic economic sectors. In Madre de Dios, we differentiate among (1) communities close to (<30 km) the capital of Puerto Maldonado; (2) "Tambopata West," a zone of settlement between Puerto Maldonado and Cusco that includes gold mining activity; (3) the "castaña zone" north of Puerto Maldonado, where

areas (settlement project, agroforestry project, extractive reserve, etc.). In each case, we define communities based on local definitions that emphasize associations among rural families in the same locality.

there are more castaña trees but land is more remote; and (4) Tahuamanu, yet further north, but where the first portion of the Inter-Oceanic Highway was paved in Madre de Dios. In Acre, the four subregions are (1) communities close to (<30 km) the state capital of Rio Branco; (2) communities around Capixaba, a young town experiencing rapid growth and located only a few kilometers from the Bolivian border; (3) communities around Xapuri and the nearby sister towns of Brasiléia and Epitaciolândia, which form a local market hub along the Bolivian border; and (4) Assis Brasil, located at the far end of the Inter-Oceanic Highway from Rio Branco in Acre on the Peruvian border. The four subregions in Pando are (1) communities along the Cobija-Sena road, up to roughly 150 km from Cobija at Puerto Rico at the near side of the Manuripi River, which lacked a bridge at the time of surveys; (2) communities along the Cobija-Extrema road, a smaller corridor also close to Cobija; (3) communities in Abuná, farther from Cobija and close to the Brazilian border; and (4) communities along the Cobija-Sena Road, beyond the river at Puerto Rico and closer to Sena (150–250 km from Cobija).

Findings

Our analysis compares migration indicators for rural communities along highway corridors in Madre de Dios, Acre, and Pando, as well as areas within each of the three sides of the frontier. We deploy resilience thinking to inform our interpretation of the migration indicators, and we seek to explain variation among sides and their subregions using the explanatory framework described earlier. Table 3 presents the findings from the community surveys. Community size (column 1), measured in terms of the number of resident families, varies among and within the three sides, with larger communities in Madre de Dios and Acre than in Pando.

However, the focus of our analysis in Table 3 is on the migration indicators.[3] Using data from the community survey on the number of families who joined and who left the communities in the past five years,

[3] For the migration analysis we take the community, and not the informant, as the unit of analysis. To obtain community-level migration estimates from our informant data, we calculated averages for reported migration values across informants for each community. We also weighted our migration analysis by community size. This provides a more accurate appraisal of migration activity by placing greater emphasis on communities with more families. Table 3 reports unweighted values for community size, since weighted averages by the weighting factor itself would distort estimates of average community size. Table 3, however, reports the weighted averages for the migration indicators. This implies that the migration rates presented do not equal the (weighted) absolute values divided by the (unweighted) community-size values, so one cannot simply calculate the absolute migration values provided in Table 3 using the community sizes in Table 3.

Table 3. Family Net Migration and Turnover, Rural Communities in the MAP Frontier (Madre de Dios, Peru; Acre, Brazil; and Pando, Bolivia), Five Years Preceding 2007, 2008

	(1) Resident Families[a]	(2) In-migrant Families[b]	(3) Out-migrant Families[b]	(4) Family Net Migration[b]	(5) Percentage Net[b]	(6) Family Turnover[b]	(7) Percentage Turnover[b]
Madre de Dios, Peru							
Near Puerto Maldonado	80.06	22.01	8.68	+13.32	+7.23	30.69	23.51
Tambopata West	185.71	36.26	4.47	+31.80	+15.55	40.73	18.86
Castaña Zone	184.54	67.99	9.56	+58.43	+14.38	77.55	20.52
Tahuamanu	39.54	32.43	5.97	+27.29	+29.19	39.22	53.94
Total	118.52	43.04	6.73	+36.48	+16.08	49.95	25.04
Acre, Brazil							
Rio Branco/Sen. Guiomard	189.09	42.69	12.54	+30.14	+6.20	55.23	22.38
Capixaba	269.50	19.80	21.49	–1.69	–0.31	41.29	15.36
Brasileia/Epitaciolândia/Xapuri	138.92	43.99	101.51	–57.52	–5.70	145.50	20.34
Assis Brasil	33.25	2.38	4.76	–2.38	–9.02	7.14	21.80
Total	146.51	38.43	53.92	–15.49	–0.71	92.35	20.40
Pando, Bolivia							
Cobija-Sena (near Cobija)	81.83	115.21	23.87	+91.34	+19.27	139.09	32.08
Cobija-Sena (near Sena)	44.22	14.57	9.92	+4.65	+8.35	24.49	29.93
Extrema	27.13	7.58	2.55	+5.02	+8.43	10.13	28.09
Abuná	34.92	17.86	0.81	+17.05	+45.22	18.67	49.96
Total	52.83	72.32	16.31	+56.02	+17.13	88.63	32.20

Source: Community Survey, 2007–2008.

Notes: [a]We report unweighted averages for resident families.

[b]All migration variables are weighted by community size (resident families). See also note 3.

we calculated community net migration (as in-migrant families minus out-migrant families) and turnover (as in-migrant families plus out-migrant families). Whereas low net migration and turnover would suggest community demographic resilience in terms of better retention of collective memory, high values for migration indicators would suggest community demographic vulnerability via erosion of collective memory.

Table 3 shows that in-migration of families to rural communities (column 2) varied considerably across the MAP frontier, and that out-migration (column 3) was usually much lower. Consequently, net migration in rural communities (column 4) is generally positive. In absolute terms, net migration appears highest in Pando, followed by Madre de Dios, with Acre exhibiting negative net migration. Given the differing community sizes across the MAP frontier, a more useful appraisal involves net migration as a percentage of community size (column 5). There we find that Pando and Madre de Dios exhibit positive net migration, whereas in Acre it is roughly zero. If we interpret these findings purely in light of road paving, it appears that rural net migration is greatest before and during road paving, but then declines afterward. However, mediating factors are also likely to be operating. Based on Table 1, we could argue that greater economic dynamism, less secure land tenure, and higher population growth rates in Madre de Dios and Pando also help explain the higher net migration rates than in Acre.

An examination of net migration within each side of the frontier is also instructive, for we gain a larger number of comparisons to better distinguish among explanations. In Pando, percentage net migration gains are larger near Cobija and in Abuná. Both are relatively close to paved portions of the Inter-Oceanic Highway, which suggests a road-paving effect on net migration. None of the other factors listed in Table 1 are consistent with this differential; neither is distance to the state capital. Interestingly, these findings suggest that road paving in Acre raises net migration in Pando via a cross-border spillover effect.

In Madre de Dios, net migration is positive in all subregions, but especially those farther from the capital of Puerto Maldonado. This suggests a distance-from-capital effect, though other factors also appear to be operating. In Tambopata West, economic dynamism from gold mining likely helps explain higher net migration; so too in the castaña zone, given high recent castaña prices. Most interesting, however, is that the highest net migration rate in Madre de Dios occurs in Tahuamanu, the only part of the state where road paving had been completed by the time of the community survey. Tahuamanu lacks a gold or castaña economy, and has a relatively small population (column 1), though it

does exhibit a relatively high growth rate (INEI 2008). This is, however, consistent with a road-paving effect.

Net migration also varies among subregions within Acre. Interestingly, the differential by distance from the state capital runs in the opposite direction of that seen in Madre de Dios. Net migration in Acre was positive only in rural communities near the state capital of Rio Branco, and net migration becomes more negative as one moves farther from Rio Branco toward Assis Brasil. Given that the Inter-Oceanic Highway was paved through the entire study area in Acre, the distance differential in net migration suggests other explanations. The most likely candidates are population size, as half of Acre's population is located in Rio Branco, which constitutes a large market for local rural production.

From the analysis so far, we draw two conclusions. First, spatial scale matters when making comparisons to evaluate the importance of road paving and other factors for net migration. At the regional level (i.e., among the three sides of the MAP frontier), while it is possible that net migration is more positive before and during paving, mediating factors also appear important, notably land-tenure consolidation, economic dynamism, and population growth rates. But at the subregional level (i.e., within each side of the MAP frontier), road paving is an important explanation for high net migration in Madre de Dios and Pando. Second, net migration is high in much of the MAP frontier. Insofar as it erodes collective memory, net migration undermines community resilience.

Table 3 also presents findings for population turnover. This also varies considerably across the MAP frontier, in absolute and percentage terms. While absolute turnover (column 6) is higher in Madre de Dios and Acre, this in part reflects their larger community sizes, so we focus on percentage turnover (column 7). Pando then exhibits the highest values, followed by Madre de Dios and then Acre. As with net migration, it appears that land-tenure consolidation, economic dynamism, and population growth rates are more consistent with turnover rates than road paving, though one might also argue that turnover is greater before and during than after road paving.

At the subregional level, differences also appear, and road paving again emerges as an important explanation. Within Pando, turnover rates vary somewhat, being higher in Abuná and (to a lesser extent) near Cobija. This difference reflects proximity to the paved portions of the Inter-Oceanic Highway across the border in Acre, though the effect is less pronounced than for net migration. In Madre de Dios, percentage turnover is highest in Tahuamanu (where road paving had been completed), and roughly equal among the other three subregions. This suggests that economic dynamism is less important for turnover than net

migration and that road paving indeed stirs population movement among rural communities. In Acre, turnover does not vary much among subregions, which suggests that locally varying factors such as distance to the state capital are not important explanations. Rather, region-level factors slowing population mobility such as tenure consolidation and low population growth emerge as more helpful explanations for low turnover.

The comparisons of turnover yield similar conclusions to the analysis of net migration. At the regional level, mediating factors to road paving appear important, but more refined comparisons at the subregional level often show that road paving accounts for greater turnover. In addition, considerable population turnover across much of the MAP frontier suggests community vulnerability rather than resilience. In five years, roughly a quarter of the families in the communities surveyed had changed.

Conclusions and Discussion

From the analysis of the MAP frontier we draw two types of conclusions about road paving and migratory activity among rural communities. First, regarding our explanatory framework, the comparisons show that road paving, along with selected mediating factors, appear related to rural migration intensity. The findings are broadly similar for net migration and population turnover. At the regional level, expectations about road paving were not met, such that migration activity was greater in areas without or just receiving paving, and mediating factors such as tenure consolidation and population growth help explain where migration was greater. At the subregional level, expectations regarding road paving were met in several instances where no other explanations fit the data. Mediating factors were also important, as well as cross-border spillover effects.

Second, with respect to our interpretive approach, the findings are cause for concern regarding road paving and the resilience of rural communities. Net migration and turnover were considerable in most of the MAP frontier, suggesting community vulnerability via the erosion of collective memory. The consequences of rapid migration for resilience concern the growing inability of established community governance mechanisms to effectively manage social conflicts over natural resources.

There are good reasons to expect that rapid migration presents a threat to resilience by undermining local governance capacity. Across the three sides of the MAP frontier, there appears to be an association between migratory activity and conflicts over natural resources. Other

data from the community survey suggest that conflicts are more common among communities in Madre de Dios and Pando, where migration is also more intense. We regard conflict as another indicator of community resilience, specifically as an indicator of adaptive capacity, such that greater conflict suggests less resilience via lower adaptive capacity to externally induced change. A full exploration of conflict and community resilience is, however, beyond the scope of this article, though we pursue this issue elsewhere.

We also view migration as one among many large-scale processes operating due to regional integration that in turn render community governance more difficult. Management of externally induced shocks becomes more difficult with rapid migration, due not only to local conflicts but also to social problems that arrive alongside migrants, even if migrants themselves are not directly involved. For example, various forms of violence have emerged in Madre de Dios and Pando. Road paving is facilitating illegal traffic, as in timber and drugs, which are crossing national borders in the MAP frontier as a waypoint in distribution chains. In Madre de Dios, one of our community informants was murdered in broad daylight in front of a local government office in February 2008 for reporting the illegal importation of mahogany from Pando (Revkin 2008). In Pando, violence erupted in May 2008 as drug traffickers reorganized on their own terms to handle expanded production, distributed from Peru through Bolivia and out via Brazil to north Atlantic markets ("Una guerra" 2008). In September 2008, political tensions in Bolivia led to a massacre in Pando that involved some 30 deaths, jailing of the prefect (governor) of Pando, and the declaration of martial law there (Romero 2008). When asked about road impacts, informants in our community survey in Madre de Dios and (especially) Acre mentioned as negative consequences the arrival of new people who bring drugs and violence.

A key caveat concerning our conclusions is that our findings refer only to a past period, which raises concerns about the future prospects for these communities, especially when paving of the Inter-Oceanic Highway is completed. Global and regional integration are ongoing processes, and they are only beginning to be felt in the MAP frontier. The Inter-Oceanic Highway is on schedule for completion in 2010, which will facilitate further integration of the MAP frontier into global commodity circuits. Other infrastructure projects are being pursued as well in the MAP frontier for purposes of regional and global integration, including those beyond the purview of IIRSA. For example, the Madeira Complex is a planned series of dams on the Madeira River at the frontier of Brazil and Bolivia that will raise the levels of rivers crossing the

Inter-Oceanic Highway in Pando as well as Madre de Dios, and provide another outlet for production in the MAP frontier (Iniciativa MAP 2008). Given that the Inter-Oceanic Highway is not yet completed, other IIRSA projects are being planned beyond 2010, and the Madeira Complex is moving from planning toward implementation, it is possible that our findings for migration activity in rural communities of the MAP frontier will prove to be conservative compared to migration in the years to come. Alternatively, completion of the Inter-Oceanic Highway could slow net migration in Madre de Dios and Pando to levels seen in Acre, though that would seem to require other changes such as tenure consolidation and slower population growth. Conversely, completion of integration infrastructure like the Inter-Oceanic Highway and the Madeira Complex could catalyze qualitatively different changes in the MAP frontier. One scenario highlights the expansion of mechanized cultivation for export, particularly soybeans and sugar cane, as well as increased oil and gas prospecting (Dourojeanni 2006; Killeen 2007). In such a scenario, increased land values might prompt rural depopulation as communities engaged in labor-intensive small-scale production are bought out or displaced by capitalized producers.

The case of the MAP frontier illustrates the complicated implications of integration initiatives such as the Inter-Oceanic Highway for rural communities. There are multiple conditioning factors that modify the impacts of road paving, which may vary across scales and involve spillover effects. The ramifications of regional integration extend far beyond migratory activity to sociopolitical, economic, and ecological alterations, which themselves may change directions over time. This makes resilience thinking useful as an integrative approach for the analysis of social-ecological dynamics (Adger et al. 2005). But it also means that multiple methods and analytical approaches are going to be necessary to adequately understand both the complicated components of social-ecological systems and their complex (nonlinear) dynamics over time. We agree with others who have asserted the importance of a "portfolio" approach to the social-ecological analysis of resilience (Young et al. 2006). The analysis presented here can be extended to a broader comparative analysis of other dimensions of resilience, such as diversity and adaptive capacity (Adger 2000; Cumming et al. 2005; Gunderson 2000). But there is also the need for multitemporal data to allow observations of nonlinear changes, as well as for modeling of relationships among system components. These in turn provide the foundations for dynamic simulation models that both capture the relationships among system components and allow observation of continuities and innovations evident in nonlinear dynamics. A challenge therein is to select the

components of social-ecological systems to be modeled, a daunting task because social-ecological systems have many interrelated components. Daunting though it may be, this task is now a frontier in the study of social-ecological change, including that in response to integration initiatives.

To the extent that economic globalization continues, there will be integration initiatives prioritizing new infrastructure, not only to improve the competitiveness of cities that serve as processing nodes in global capital and commodity chains (Scott 1998) but also to incorporate resource-rich regions into distribution circuits to feed the processing nodes (Killeen 2007). Analysis of rural communities in regions receiving new infrastructure for integration thus becomes crucial for understanding the social and ecological ramifications. But because the literature on the social impacts of infrastructure is scattered and fragmented, the linkage of the sociological literature to global integration via infrastructure remains tenuous. There has indeed been increasing sociological analysis of globalization (McMichael 2000), notably regarding questions of the continued relevance of states and national territories for understanding regional development (Robinson 2002; Sassen 2006). But there remain opportunities for better understanding global integration via infrastructure projects through the application of insights from the sociological literature on globalization. One example involves the role of the state in transboundary infrastructure projects and the social response, whether to support such infrastructure or to mobilize in protest. Further challenges await scholars willing to analytically take on both the social and ecological aspects of infrastructure projects.

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