

Ecologies and Politics of Health

Human health exists at the interface of environment and society. Decades of work by researchers, practitioners, and policy-makers has shown that health is shaped by a myriad of factors, including the biophysical environment, climate, political economy, gender, social networks, culture, and infrastructure. Yet while there is emerging interest within the natural and social sciences on the social and ecological dimensions of human disease and health, there have been few studies that address them in an integrated manner.

Ecologies and Politics of Health brings together contributions from the natural and social sciences to examine three key themes: the ecological dimensions of health and vulnerability, the socio-political dimensions of human health, and the intersections between the ecological and social dimensions of health. The thirteen case study chapters collectively present results from Africa, Asia, Latin America, the United States, Australia, and global cities. Part I interrogates the utility of several theoretical frameworks and conventions for understanding health within complex social and ecological systems. Part II concentrates upon empirically grounded and quantitative work that collectively redefines health in a more expansive way that extends beyond the absence of disease. Part III examines the role of the state and management interventions through historically rich approaches centering on both disease- and non-disease-related examples from Latin America, eastern Africa, and the United States. Finally, Part IV highlights how health vulnerabilities are differentially constructed with concomitant impacts for disease management and policy interventions.

This timely volume advances knowledge on health–environment interactions, disease vulnerabilities, global development, and political ecology. It offers theoretical and methodological contributions that will be a valuable resource for researchers and practitioners in geography, public health, biology, anthropology, sociology, and ecology.

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Ecologies and Politics of Health

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Foreword

Integration has become the hallmark of much research and scholarship in the first part of the twenty-first century, with few topics of study benefiting more than that of human–environment relationships. This integration runs contrary to the dominant analytical and theoretical trends of the twentieth century, which separated the human (social) and environmental (biophysical) domains of these relationships. This separation was a response, in part, to nineteenth-century attempts to reduce understanding of the human subsystem to an environmental one, and, subsequently, the conceptual and theoretical successes emerging from the study of the human subsystem independently. The current return to integrative understanding of human–environment relationships follows from breakthroughs in genetics and evolutionary-led sociobiology, and from a growing concern with the Anthropocene, in which humankind has become a force approaching nature in affecting the Earth system. In either case, the need to put the pieces of the human–environment puzzle back together again is increasingly recognized in both research and practice. For the last concern, advances in complex adaptive systems research have helped to formalize characteristics and outcomes of the system as a whole, not found in an examination of its individual parts, such as legacy effects, non-linear relationships, thresholds, and emergent properties. Real-world applications seeking more sustainable human–environment conditions reveal that system complexity leads to different outcomes in different contexts, indicating that panaceas are unlikely.

Multiple approaches, or topical domains associated with an approach, seek to understand phenomena and processes that are the outcome of human–environment relationships—risk–hazard/vulnerability studies, political ecology, human ecology, sustainability science, disease/health ecology, to name a few. *Ecologies and Politics of Health* adds another: “hybrid sociopolitical–ecological health.” As a cluster, these approaches examine the systemic whole through various lenses of integration. This orientation, however, does not render reductionist approaches mute. We are not at some moment in which “normal science” has become passé. Indeed, much of it underpins complex systems analysis and forms the foundation for understanding the processes at play in either of the human–environment subsystems, as it does in the medical sciences informing human health research. Caution is warranted, however, for those cases in which system principles or lessons may be gleaned from one subsystem and applied uncritically

to the other or the system as a whole—a tendency, if unintended, emanating from some venues in the natural and complex system sciences. Likewise, caution is warranted regarding “confirmational bias”, which Andrew Vayda (2009) finds recurrent in some social–environmental systems approaches anchored in the social sciences, especially those employing the label “political”. This bias involves uncritical acceptance of a metatheory that diverts attention away from alternative factors and processes at play in the outcome (event or phenomenon) of the system. As I understand them, the hybrid approaches in this volume heed these cautions.

The label hybrid typically carries several meanings: (i) the use of quantitative and qualitative data and analytics, or mixed methods; (ii) an appreciation for multiple explanatory perspectives used to frame and inform the human–environment problem; and (iii) the development of an explanatory framework that fuses or mixes post-positivist, structural, and constructivist perspectives. The last meaning is largely implied in calls for integrated theory and is sufficiently ambitious, if not logically impossible, to deter attention from it. Rather, hybrid human–environment approaches, more often than not, employ alternative understandings to inform the base research approach for the practitioner. Hybrid practice is intended to enlarge the phenomena and processes considered in the research problem by exploring multiple ways of identifying them and understanding their possible roles.

What does all this mean for research on human health? Conceptually, a wide range of factors, processes, principles and theories are open to consideration and actually explored. For example, the suspicious P (population), at least from the lens of some political ecologists, is considered along with unequal entitlements and empowerment, factors that may be omitted in some conventional assessments. The attributes of P, including its sheer size and density, matter for many human health problems, but these attributes also include age, gender, and social status, among others that affect entitlements to healthcare. Analytically, alternative ways of knowing are employed as checks and balances on one another. For example, quantitative tests or models are informed by qualitative understanding, altering their configuration and, presumably, their performance. Likewise, metatheory-led narratives may be put to test, when applicable, potentially revealing the role of variables and processes otherwise muted by the metatheory. In short, hybrid human–environment approaches—or at least those that capture my attention and are represented in *Ecologies and Politics of Health*—appear to be less concerned with championing an explanatory perspective or metatheory and more concerned with understanding the multiple dimensions of complex relationships through mixed methods.

This understanding resides firmly in Pasteur’s quadrant of a pure-to-applied research matrix (Stokes 1997), in which basic research is undertaken on societally framed problems with an eye towards informing real-world solutions. This link of research to practice reinforces the need to address the multiple dimensions of human health systems because their complexity leads to variance in place-based outcomes of otherwise similar systems. Such variance can prove problematic for setting policy or programs, an impediment that can

be amplified where decision-makers are circumscribed by mission, political boundaries, or other limits that mute their interest or capacity to deal with the health problem holistically. How might such bounded decisions be made more congruent with the complexity of sociopolitical–environmental system associated with the health problem? One current popular response is through the co-production of the problem and its analysis by the scientist–researcher and the practitioner–decision-maker.

Human health science has always involved co-production, at least in the sense of research undertaken on societally defined problems. Recall the research quadrant named for Pasteur (above) and the research undertaken by the World Health Organization or the US Centers for Disease Control and Prevention, all of which respond to societally defined health problems. Recall as well the number of successes from pasteurization to the global eradication of smallpox and rinderpest. These successes, as I understand them, are founded largely on technomethodological breakthroughs or panaceas. In contrast, this volume points to co-production that, more often than not, moves well beyond simple panaceas. The problem framing and solutions account for the concerns of different socioeconomic units (e.g., stakeholders), especially those actually affected by the health problem, the roles of different levels of decision-makers, institutions and governance, and the participation of a range of research specialists (medical to social). Just as the hybrid approaches in this volume inform us that understanding human health issues systemically requires an expansive perspective, they also point to complex co-production linkages for successful health applications. This, I believe, is a major take-away lesson of *Ecologies and Politics of Health*.

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References

- Stokes, D. E. (1997) *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, DC: The Brookings Institution.
- Vayda, A. P. (2009) *Explaining Human Actions and Environmental Change*. Lanham, MD: AltaMira Press.

3 Capitals and context

Bridging health and livelihoods in smallholder frontiers

*Leah K. VanWey, James R. Hull
and Gilvan Guedes*

Introduction

This chapter approaches the complex, dynamic, and multiscale relationships entailed in the politics and ecologies of health holistically, treating health as one of multiple competing investment priorities for households occupying smallholder frontiers. We draw upon insights from theory viewing health as a form of human capital (Grossman 1972) and poverty as a lack of ability to invest (Reardon and Vosti 1995), and from demographic research pointing to the long-term payoffs to early life health (Hayward and Gorman 2004). Health for us is thus not the lack of an event (e.g. disease, malnutrition) but a dynamic process of household investment in nutrition, preventative medicine, and appropriate treatment of disease (Berman *et al.* 1994). Our approach merges these insights with the livelihoods research tradition (Ellis 1998; de Sherbinin *et al.* 2008) and considers the multiple capitals influencing the capabilities of smallholder families to avoid illness and improve health (Bebbington 1999).

Household investments change the context in which future decisions are made, a process we call endogenous evolution of context. We hypothesize that early in frontier development, smallholders pursue livelihood diversification to diversify their capital portfolios and increase resilience, while in mature frontiers it becomes possible through conversion of financial capital into other capitals to pursue specialized livelihoods while maintaining diverse capital portfolios. Thus, livelihood diversification is predictive of success early in frontier development, but a signal of hardship in later frontier stages. These predictions are typical of a complex system: context-specific, sensitive to initial conditions, and displaying emergent properties.

Smallholder frontiers provide empirical and theoretical leverage to examine complex systems by allowing us to enter at a moment when settlers have not previously been influenced by the environment that they are entering. We can therefore isolate the effects of the humans on the biophysical environment without these effects being contaminated by reciprocal relationships. In addition, the co-location of people and environment in smallholder frontiers closely ties decision-makers to environmental impacts (Axinn *et al.* 2010; Moran 2010).

We present a flexible model of livelihoods and investments based on dynamic changes in (i) the investment returns to different type of capital, (ii) the stocks of

each capital class, and (iii) the diversity of household portfolios. To ground our theory empirically, we focus on land use, off-farm employment and migration as key smallholder livelihood strategies in frontiers, tracing their implications for household health and well-being. Land use by farmers in frontier regions is an essential factor mediating the relationships between humans, ecological well-being, and health (Saxena *et al.* 2005). In the cases detailed here, food and financial income from farm production, off-farm employment, and migrant remittances represent strategies that allow households to invest in health (e.g. through nutrition, medications, or immunizations).

We marshal empirical evidence for our theory from published and unpublished results from long-term collaborative research projects involving five frontier areas in Brazil and Thailand. This chapter begins by describing smallholder frontiers and these five specific frontiers, then presents our framework and discusses the interaction between elements as they affect health at the household level. We conclude with a discussion of the significance of our framework for the study of many different phenomena in coupled human and natural systems, focusing on implications for health policies.

Health and household dynamics on frontiers

Smallholder frontiers

Our definition of frontier is purposefully minimal, to emphasize the broad applicability of our theory. The essential characteristics of frontiers are dramatic increases in population density via in-migration, improved accessibility, an absence of established social institutions, and an abundance of natural resources relative to other areas. Frontiers provide opportunities for achieving general well-being and amassing financial wealth with small stocks of human, social, and physical capital. Only natural capital and the human labor to exploit it are required. This acts as a strong incentive for the poor to migrate there (Bilsborrow 2002). Young adults, some with children, are typically over-represented in these migrant streams, further fueling rapid population increase at frontier opening (McCracken *et al.* 2002).

Frontiers represent opportunity to young settlers, but the breadth of migrant origins creates challenges to social organization, requiring creation of new social institutions. Settlers separated from kin, tradition-based hierarchical social relations are leveled through mixing of ethnicities and backgrounds, and affinity-based social ties are usually reformed on the frontier. Typically remote from government centers, settlers on frontiers must also create their own political institutions. Markets for goods, labor, and land must be created, usually through cooperation among settlers. As new families enter and begin converting natural capital to other forms of capital, ecosystem functioning, human institutions, and population structure respond. In turn, families respond to these shifts in context, altering the decisions they make about livelihood strategies and forcing readjustments to their capital portfolios. Through these endogenous feedbacks, the ecosystem and human environment are continuously modified.

We use findings from four sites in the Brazilian Legal Amazon and one in Northeastern Thailand to illustrate and motivate our theory. Details of the data collection and analyses appear elsewhere (D’Antona and VanWey 2007; Moran *et al.* 2005; Rindfuss *et al.* 2009); here we emphasize site characteristics relevant to theory building and comparison. Chief among these is the process of frontier settlement that began in all five regions during the mid–20th Century. Figure 3.1 shows the timing of in-migration to each state and the subsequent increase in population density.

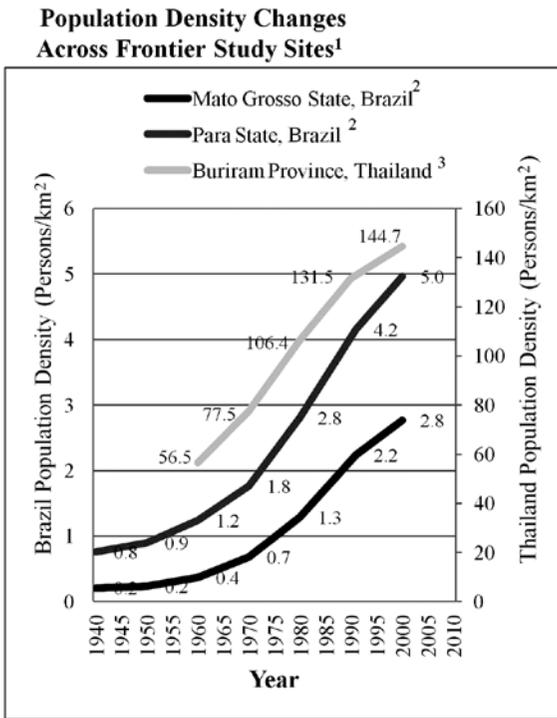


Figure 3.1 Population density changes across frontier study sites.

Notes

- Two of the Brazilian sites are located in the state of Pará and two in the state of Mato Grosso. We present population densities at the state or *changwat* scale rather than the district (*município* or *amphoe*) level due to instability in the political boundaries of these frontier districts. Thus, we have three time series, not five.
- Source: Brazilian Demographic Censuses of 1940, 1950, 1960, 1970, 1980, 1991, and 2000. Instituto Brasileiro de Geografia e Estatística. (Available at <http://www.sidra.ibge.gov.br/bda/>).
- Source: Thai Population and Housing Censuses of 1960, 1970, 1980, 1990, and 2000. Changwat Level Summary Tables. The National Statistics Office, Kingdom of Thailand. Data not available at Changwat Level prior to 1960.

Brazil

Our Brazil sites represent varied settlement histories, livelihoods, and levels of human health and well-being. Altamira lies on the Trans-Amazonian Highway (BR-230), and was an early demonstration settlement area. Colonists brought from other regions of Brazil were granted land for agriculture, provided they cleared a portion, improved it through planting crops and adding buildings, and paid a nominal sum to the government (Moran 1981). Early settlement was characterized by high rates of deforestation, malaria, farm failure, and onward or return migration of some initial settlers. These failures in part resulted settlers lack of knowledge about biophysical conditions of farms. Today, Altamira retains a smallholder character with small- to mid-scale ranching and agriculture, and an increasing urban orientation of landholders (VanWey *et al.* 2008; Walker *et al.* 2000). For discussion on frontier settlement and its implications for human health in a similar frontier, see Chapter 7.

Santarém sits at the confluence of the Amazon and Tapajós rivers, at the northern terminus of the Cuiabá-Santarém Highway—the “Soy Highway.” A traditional port city, Santarém has long functioned as a trade center between the upper Amazon and the estuary. A deep-water port was constructed in 2003 to permit direct export of soy to international markets (Steward 2007). Agricultural settlement of surrounding regions began in the early twentieth century, but Santarém’s low-fertility soils supported low crop yields, leading much of the region to be fallowed again (D’Antona *et al.* 2006; Fudemma and Brondízio 2003). Unlike the government-sponsored colonization of Altamira, much of the settlement of Santarém was spontaneous, and colonists came from nearby, suggesting that they had greater understanding of the region and its limitations. Settled properties here were, and remain small and precarious today.

Two sites in Mato Grosso represent yet another history, centered on the arrival of larger (but still familial) farmers. Both were colonized around the 1980s and experienced rapid land clearing for production. Both also benefited from more favorable soil and climatic conditions and from more similarity to the origin areas of settlers. The first site, near Canarana in the east of the state, was colonized by cooperatives of large owners from the south and southeast of Brazil (Jepson 2006). This tradition of large owners and hierarchical labor relations among owners, managers, and farm workers persists today even while the original ranching is giving way to some row crop agriculture. The second site, Lucas do Rio Verde, in the center of the state, was also settled by larger landowners and large row crop farms continue here today, but are supported by verticalized industrial agribusiness. The county houses a processing facility converting raw soy into oil and meal, an incubating operation for chicken eggs, and poultry and swine slaughterhouses. Recent investment in the region by Brasil Foods Corporation (formerly Perdigão) and Sadia has led to the rapid expansion of confined poultry and swine operations that take advantage of local production to feed their stock. The agribusinesses in town coexist with strong local family involvement in farms and little absentee ownership.

Thailand

Nang Rong District, located in northeast Thailand, experienced rapid demographic, economic, and environmental change beginning in the mid-twentieth century (Entwisle *et al.* 2008; Walsh *et al.* 2005). Rapid in-migration and land clearing ensued, reducing forest cover from 50 percent in the 1950s to less than 20 percent by century's end (Entwisle *et al.* 2008). As in Brazil, settlers took advantage of land tenure laws to claim lands and gain informal rights through clearing the land, in this case along rivers and floodplains, and by making improvements supporting paddy rice cultivation (Keyes 1976; Entwisle *et al.* 2008; Phongphit and Hewison 2001). Gradually, rice production has expanded upward from alluvial plains to less suitable environs. When demand for first jute and then cassava (for European livestock) spiked in the 1970s and 1980s, agricultural production expanded further into the uplands, driving deforestation (Entwisle *et al.* 2005; Rigg 1987). Agricultural mechanization first begun in the 1980s was not fully incorporated for another two decades, leaving many agricultural activities to be performed by hand during the period examined here (Hull 2008). Today, small manufacturing sponsored by private development initiatives supports limited local off-farm employment in higher skill jobs (Alva and Entwisle 2002).

Health through the lens of a livelihoods-context capitals framework

What follows is a condensed introduction to our framework, which theorizes the linkages between development, land-use and land-cover change, and household livelihood transition across smallholder frontiers. It builds upon the conceptual frameworks of Bebbington (1999), Lambin *et al.* (2003), Curran and DeSherbinin (2004), Axinn *et al.* (2010), and McCusker and Carr (2006). A response to calls for an integrative theory of coupled human and natural systems, this framework speaks to multiple substantive domains, including health, deforestation, out-migration, and changing economic exchange relations. For a related discussion on how to conceptualize human health, see Chapter 2.

Common to all of these processes is the interdependency of household-level decision-making and evolving endogenous context. Our framework, depicted in Figure 3.2, has five principal elements. In the lower left are capital portfolios, consisting of stocks of each of five capitals—natural, physical, social, human, and financial—which constrain and enable livelihoods. In the upper left are returns to each class of capital, which also shape livelihoods and are impacted by the endogenous evolution of context. Context, represented in the upper right, consists of six major dimensions—accessibility, demographic, social, economic, political, and environmental—which respond to the livelihood decisions of actors, while also influencing future decisions. In the lower right we depict key outcomes of interest to researchers and policymakers, particularly health, which are determined by livelihood decisions. We now describe each of these elements, first describing the articulation between health outcomes, well-being, and livelihoods.

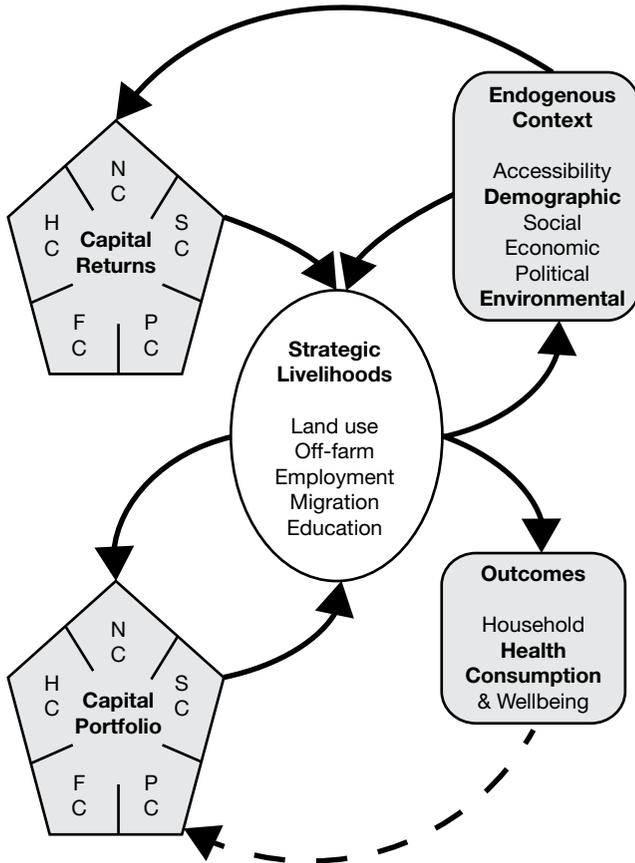


Figure 3.2 Human and ecological well-being co-evolve over time.

Note: health intersections are emphasized in bold.

Health, multidimensional well-being, and livelihoods

In smallholder frontiers households are the locus of income pooling and joint consumption, including joint decisions about investments in various forms of capital and about key health-promoting behaviors. The pursuit and maintenance of health is an important and distinct goal of household decision-making calculus. Ill-health decreases income and increases costs, and may be conceptualized as a factor competing with other dimensions of well-being for scarce household resources, thus exerting unique influence on livelihood decisions (Hampshire *et al.* 2009; for a related discussion on disease as shock to livelihood systems, see Chapter 14 of the present volume). Simultaneously, good health constitutes a basic element of human capital, linking our framework to early work on human capital showing health as equivalent to education and knowledge (Becker 2007; Grossman 1972). Health is connected to household well-being by an endogenous

system of *health status, nutritional intake* and *labor productivity* (Joffe 2007). Ill-health events can drive impoverished households into a vicious cycle of depleting multiple forms of capital to cover costs of the illness (including treatment, food, medication, transportation, but also the shadow price of an absent labor). This cycle affects the ability of households to maintain optimal nutrition, leading to productivity declines and increasing vulnerability to further ill-health shocks (Sauerborn *et al.* 1996; Joffe 2007). While this is an endogenous system at the household level, decisions about health investments are not made in a vacuum. The changing contexts of healthcare institutions and accessibility influence the costs of health.

Capital portfolios

We argue that households pursue livelihoods in order to maximize stocks of preferred capitals, where subjective preferences for particular types of capitals evolve along with the frontier. In turn, households' stocks of capitals (collectively "portfolios") simultaneously constrain and enable various livelihood decisions. We consider five classes of capital: natural capital (e.g. access to water, forest products), physical capital (e.g. machinery, buildings), financial capital (e.g. wages, remittances, public transfers), human capital (e.g. health, education, on-the-job and on-the-farm training), and social capital (e.g. familial and social networks, associations/unions, generalized social trust). The relative share of a household's total portfolio constituted by each type of capital is altered as the household chooses livelihood strategies that draw on existing forms of capital in the hopes of obtaining more of the same or converting lower-return capitals into forms of capital with higher returns. The strategic use of capitals based on returns is key to understanding health impacts on capital portfolios. If a health shock induces a household with limited capital diversity to capital depletion, the ability to overcome health shocks is further compromised, since the absence of specific capitals prevents households from taking advantage of potential higher returns (Joffe 2007). This iterative process of capital accumulation, depletion, and conversion to alternative forms is summarized by the arrows flowing from capital portfolio to livelihoods and back in Figure 3.2.

Capital returns

It is useful to distinguish the amounts of various capitals in a portfolio from the advantages and disadvantages of possessing them within a specific context. Returns to capital are dynamically shaped by context, subsequently influencing livelihood strategies in the same manner as capital portfolios themselves (depicted by the arrow from endogenous context to capital returns in Figure 3.2). Considering either in isolation provides an incomplete explanation of household behavior. These two major elements of the framework do not interact directly, however. Instead, they impact one another indirectly through livelihoods and endogenous context.

Figure 3.3 shows the stylized empirical facts underlying our theory of changes to capital portfolios and capital returns over time in smallholder frontiers. Returns to each form of capital over frontier development are depicted in Figure 3.3a, starting with settlement by smallholders and ending with the integration of the frontier into national and global systems. Figure 3.3b shows how distributions of capitals in household portfolios change over the same span. The net effect of frontier development is conversion of a substantial amount of natural capital into financial, physical, and human capitals which begin providing greater returns by the later stages of development. Figure 3.3b can be conceptualized as the static result of the dynamic transitions depicted in Figure 3.3a. We briefly describe these shifting returns and stocks.

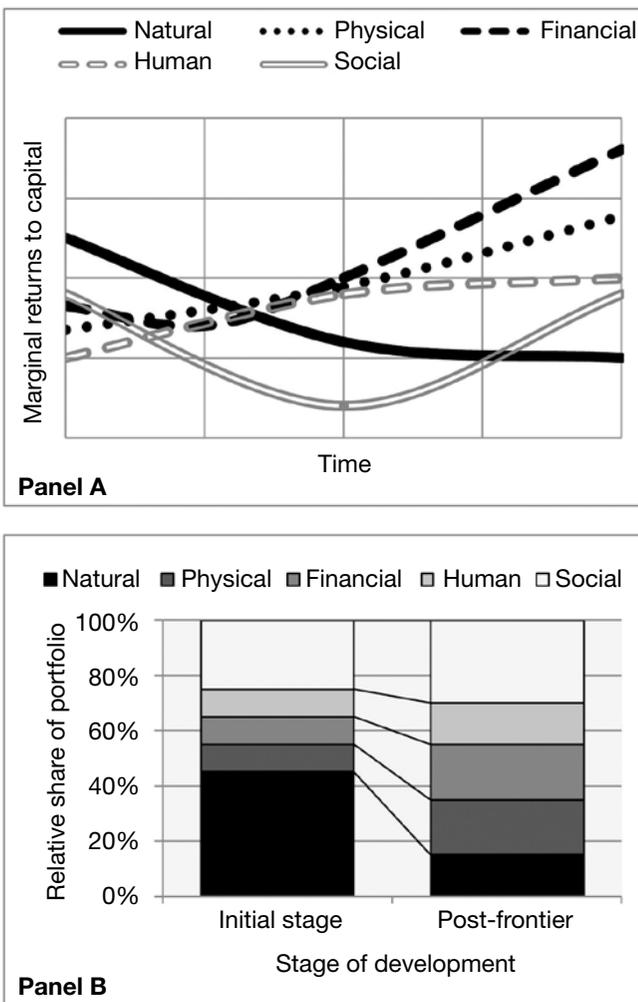


Figure 3.3 Capital returns and portfolios change as smallholder frontiers transition.

Natural capital

Natural capital (NC) is especially important during the initial phase of frontier development because economic institutions are limited. At this point, subsistence is largely dependent on ecological services derived from NC. Off-farm employment and markets for the purchase of goods both expand as the frontier develops, reducing households' dependence on natural resources to meet consumption needs. Returns to NC likewise decrease as households adopt newer and more efficient technologies for agricultural production (Figure 3.3a). The relative representation of NC in total household portfolios declines as households diversify into other capitals, particularly human (Figure 3.3b). Declining returns remove incentives for households to reinvest in NC through practices like fertilizer application or erosion control. In Altamira, rather than investing in improvements to common poor soil types, settlers clear more extensive areas and plant hardy pasture grasses that will survive with few inputs (Moran *et al.* 2002). In Santarém, the depreciation of NC over time is evident in the belief that forest is a nuisance impeding other property uses, leading buyers to pay a premium for cleared land (Adams 2008).

Social capital

A distinctive U-shaped curve characterizes returns to social capital (SC). This reflects the synthesis of monotonically decreasing returns to bonding SC (strong bonds among close associates) and the monotonically increasing value of bridging social capital (relations that connect people across much larger social distances; Woolcock and Narayan 2000). The value of bonding SC decreases as population and markets grow and households become either internally diversified or possess enough FC to purchase goods to meet needs. With further development, social networks connect rural households to larger networks of goods, information, and opportunities, but these networks necessarily embody bridging SC rather than bonding SC. Early in frontier evolution, social networks enable settlers to overcome poor or nonexistent labor and credit markets to achieve production essential to well-being. Networks also promote investment in human capital in the form of health by putting settlers in touch with information and access to improved healthcare, and providing an important source of care-giving during ill-health events (Smith and Christakis 2008). But while current theories about social network impacts on health implicitly assume a static social structure, our theory explicitly argues that the content and form of social networks, and the overall returns to social capital vary endogenously over time, with corresponding variations in the health implications of network structure.

In Brazil, for example, when returns to NC are high, bridging connections to business owners and government officials in São Paulo or Belém are of little help in clearing, planting, and harvesting, and therefore provide little in the way of assistance with health investments. With improving accessibility, such connections yield higher returns, helping households secure access to distant markets, documentation for credit, and favorable access to education and quality

healthcare, while bonding ties continue to provide access to the same opportunities to which a household already has access. The competing effects of declining investment in bonding SC and increasing investment in bridging SC lead to a small net increase in the SC component of household portfolios (Figure 3.3b), but large potential changes in the ability of a household's network to respond to ill-health episodes.

Physical capital

Settlers initially have little physical capital (PC): machinery, buildings, or landesque capital such as bunds, fences, or irrigation systems (Blaikie and Brookfield 1987). Households are often PC-poor before relocating to the frontier, and are further limited to what can be easily transported. PC increases steadily over time (Figure 3.3b) through conversion of NC and FC. Early increases in PC are essential for the health dimension of household well-being; improvements to housing stock reduce disease risk through improving water access and reducing exposure to disease vectors. Returns to PC (Figure 3.3a) are initially low, but increase as markets develop for local sale and export of surplus production, incentivizing investment in machinery such as tractors or trucks. Early on in our Brazilian sites, households extracted NC such as timber to construct houses, furniture and other PC such as livestock fences. In Nang Rong, the early years saw construction of PC such as ponds, fish weirs, and elevated buildings for keeping equipment dry. As incomes increase, households also invest in house improvement (Rindfuss *et al.* 2007). Later still, some acquire enough cash income from production or employment to purchase chainsaws, refrigerators, radios, vehicles, and other durable goods.

Human capital

Human capital (HC) levels are low at frontier settlement (Figure 3.3b), but increasing returns over time (Figure 3.3a) lead households to seek more and different HC. Early on, site-specific knowledge and pure labor power drive agricultural success (Moran 1981) while at later stages returns are highest to formal HC like education and work experience. Upon arrival, migrants have low site-specific HC and may experiment with the new biophysical environment as an investment in HC. As noted above, they also make investments in PC that are simultaneously investments in HC as the health of family members improves. In early years in Altamira and Santarém, we see experimentation and heterogeneity at the property level in land use, while later years are characterized by specialization in the highest return crop (given soils, water and accessibility; McCracken *et al.* 2002; VanWey *et al.* 2007). Early villages in Nang Rong were situated on the margins of river flood plains where rice could be reliably cultivated using the traditional paddy system, with which most settlers were already familiar, only expanding in other agroecological regions once settlers developed the site-specific HC needed to exploit them (Entwisle *et al.* 2008). As further investment in site-specific HC yields lower marginal returns, families adopt

new strategies of investing in formal HC, requiring strategic decisions about which members receive additional education and which stay “down on the farm” (Curran *et al.* 2004).

Financial capital

Returns to financial capital (FC) also follow a U-shaped curve (see Figure 3.3a), but the upturn occurs before that for SC. FC returns are high when establishing a farm, but decline again until the frontier becomes well-integrated with broader markets. In the interim, even households with high levels of FC experience low returns. In our study areas, only the construction of better roads facilitating exports and the development of labor markets allowed some households to invest FC into production through purchases of PC and labor. With improvement in infrastructure and development of urban markets, returns to FC rapidly increase (the upward turn in Figure 3.3a). In the context of limited credit markets or higher rates for credit, characteristic of our study sites (Ludewigs 2002), FC returns respond even more to these improvements. Once the rate of return to investments in FC is reliably increasing, households seek to rapidly expand their potential sources of cash income. Migrant remittances, profits from the sale of cash crops, off-farm employment, rental of land and physical capital, and the rapid development of a monetized labor market are paired with “public” strategies for FC accumulation such as the rural retirement and Bolsa Família programs in our Brazil study sites, subsidized credit (as we see in the rural Brazilian Amazon), and monies for community development from NGOs in Nang Rong (David and Viravaidya 1986).

Returns to each of these forms of capital are altered regularly by changes to multiple dimensions of context (upper right box of Figure 3.2). We discuss these dimensions in the next section, highlighting the way in which they change endogenously as household investment decisions change the context in which future returns are determined.

Endogenous context

Understanding the endogenous evolution of context is vital to explaining how and why livelihood strategies change over time. Our approach goes beyond existing work on the political economic context for decision-making by characterizing context as dynamic, endogenous, and multidimensional. While we do not discount the importance of exogenous changes in determining returns to capitals, our goal is rather to highlight the predictable ways in which context changes endogenously. Frontiers are an ideal natural laboratory for the study of endogenous changes in each of these domains.

Livelihood strategies are determined in a given time period by capital portfolios and returns, as well as by context (Figure 3.2, center). Livelihood strategies also modify the multiple elements of context. These factors influence in turn the returns to various forms of capital in the future (arrow at top of Figure 3.2). In considering the temporal scale of changes, we distinguish slow,

medium, and fast endogenous feedbacks observable empirically (cf. Lambin *et al.* 2003). This distinction parallels recent interdisciplinary health systems frameworks that classify endogenous system processes as either proximal or distal (Eisenberg *et al.* 2007, Batterman *et al.* 2009). At the finest temporal scale, we consider endogenous change from year to year, comprising, for example, this year's crop choice in response to last year's yield or prices. At the medium scale, we consider several years to approximately 15–20 years, the scale over which, for example, environmentally-oriented social movements may form, lobby for changes, and achieve policy changes. We limit the upper end of the continuum to changes that occur on the scale of approximately 20–40 years, the scale of a human generation, over which, for example, childbearing decisions by parents modify regional populations and feed back into the fertility choices of the next generation. Figure 3.4 summarizes the time-scale dependencies for representatives of each dimension of endogenous contextual change.

Accessibility

The timing of accessibility improvements determines the speed at which frontiers move along the curves in Figure 3.3a, raising returns to PC and the conversion of NC through agriculture and influencing the speed at which households move toward more diversified and monetized livelihoods. A dramatic exogenous change in accessibility marked the opening of the frontier in each of our study areas with externally initiated road-building projects. But we focus here on the ways in which accessibility subsequently changes endogenously across multiple spatial scales. As farmers move across properties and travel to local urban areas and other destinations, paths become small and then larger roads, especially as greater FC permits the purchase of motorcycles and trucks. The utility and permanence of paths and small roads increase as a function of land use and other decisions within a year while the need for and construction of all-weather roads happens over years to decades. The construction or paving of state or federal highways is a more complicated and long-term process, but it too depends on the ingenuity, labor, and desires of local populations, and on their ability to make claims on non-local actors (Figure 3.4). State or federal roads will at times follow existing roads because they are the path of least resistance (physically and socially), a phenomenon that has been well documented in regions proximate to our Altamira study area, where informal roads, most built for logging, became formalized all-weather roads and even state highways (Arima *et al.* 2005; Perz *et al.* 2007). Accessibility also modifies household investment in HC, including healthcare, by changing the costs of such investments. The nominal and lost-labor costs of a visit to a clinic or to the city to buy medicine decline dramatically as transportation infrastructure develops. As households invest more in this form of HC, demand increases, and local social leaders and politicians can make added demands on the central government for new clinics or more funding for existing clinics (in settings such as ours where healthcare is publicly funded).

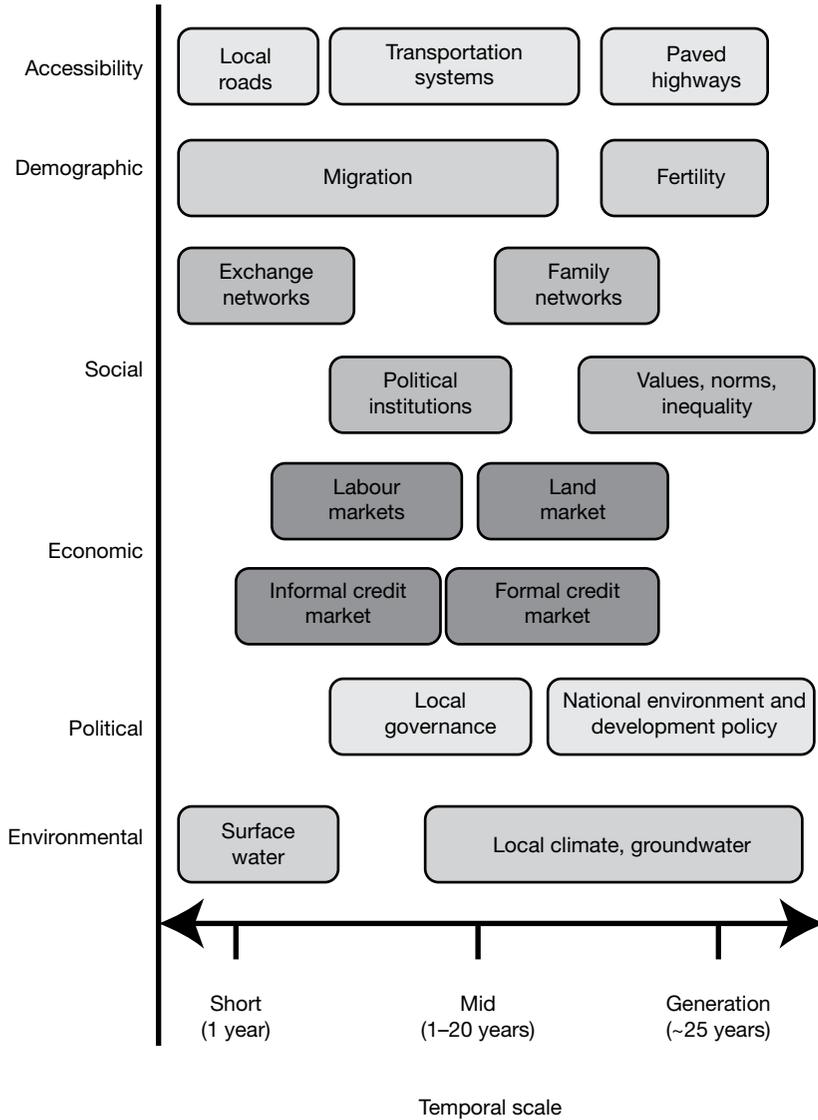


Figure 3.4 Time scale of key endogenous feedbacks.

Demographic factors

Across generations, fertility decisions and health investments that alter mortality rates change the demographic context endogenously. These actions are particularly relevant in frontiers, where age distributions are weighted heavily toward the child-bearing years. As these large cohorts of young adults age, the characteristic bulge moves through the age structure, followed by an “echo” bulge of their children, with the size of this echo influenced by infectious disease mortality and

a household's ability to invest in health (Joffe 2007; Russell 2004). Between these bulges lie smaller cohorts (in the absence of continuous in-migration). The size of cohorts can influence labor availability, with small cohorts creating labor scarcity and changing the context in which agricultural and HC investment decisions are made. Migration also endogenously changes the context of future household decisions. As connectivity with other regions increases and population exceeds the capacity of local labor markets to absorb it, temporary out-migration on a seasonal or multiyear basis becomes an alternative path to meeting consumption needs and accessing scarce FC (VanWey *et al.* 2009). In our Brazilian sites, daily or weekly commuting between cities and urban hinterlands occurs for work or leisure. In Nang Rong, we observe seasonal migration for farm work in the region combined with longer-term migration to urban centers for service, factory, and construction jobs (Korinek *et al.* 2005). These population movements further alter livelihood strategies as some migrants leave children in their parents' care (Piotrowski 2009).

Social factors

Formal and informal social institutions develop over long human histories. Some shared institutions arrive with settlers. Others, such as cooperative agreements about labor sharing and local governance arrangements, must develop rapidly in frontiers. Settlers in a new frontier may share national or regional histories, but often have no shared local history, forcing them to devise new institutions governing collective behavior. Simple collective governance systems may develop rapidly (less than a decade) to address inadequate or non-existent institutions on frontiers, but more complex governance such as organized parties and political systems takes considerably longer (Figure 3.4). Another important set of institutions regulate how land is intrinsically valued, and these develop on the scale of generations. Since settlement, norms have emerged in Altamira that identify "clean" land as preferable to "dirty" land. "Clean" in this context is land cleared of trees and shrubby vegetation, with fences and views to the horizon, and is interpreted as the mark of a superior farmer. The normative land-use pattern in much of Santarém, meanwhile, would be viewed in Altamira as the hallmark of the lazy farmer, with its mixed areas of fallow, fruit trees, intercropped annuals, and native vegetation, which obstruct clear views of the horizon (Adams 2008). Such emerging value systems have important impacts on livelihood and land-use decisions in critical ecosystems throughout the globe. As frontiers age, the social networks linking various social entities ranging from individuals to state actors change. As Figure 3.3 suggests, such connections have high returns initially, and many sorts of new networks emerge in the space of a few years following frontier opening. By investing in production for sale, farmers then form new, longer-distance networks. Similarly, migration for employment creates longer-distance networks. In Nang Rong these pass information about family planning options (Entwisle *et al.* 1996), information about job prospects (Curran *et al.* 2005), and FC in the form of remittances (Piotrowski 2006).

Economic factors

Development of markets for labor, credit, and land directly impact agricultural production, land use, and ecological change, as well as household well-being. Equally important, development of these markets permits households to pursue more diverse livelihoods and capitals. Labor markets develop slowly in most frontiers for two reasons. First, scarce access to monetary currency in many frontiers constrains the development of monetized labor systems. Second, abundant land resources and low efficiency require that most of a household's labor be invested in its own production. It takes time for population dynamics (in-migration and natural increase) and income growth (external investment or internal accumulation) to reach a relatively stable equilibrium in which a labor market can be sustained (Figure 3.4). Credit markets also take time to develop, making room for informal credit markets and mutual aid societies to develop for the smoothing of consumption and to support investments in new activities (Alvi and Dendir 2009; Boucher and Guirkinger 2007). Such groups may take a decade or more to develop (Figure 3.4), both because the trust that underlies them is slow to solidify and because some monetary accumulation is requisite. The process can be accelerated if demand for credit and frontier accessibility are high enough that outside actors have incentives to provide credit, as has occurred in much of rural Brazil, where demands (and qualifications) for credit are artificially inflated by public provision of credit.

Political factors

Political factors consist of formal laws governing, for example, labor relations, forest exploitation, taxes, and education, as well as informal but mutually recognized organizations that allocate power and resources among people. Traditional (post-colonial) Brazilian power relations follow a patron–client model, with a small group of individuals controlling access to resources among their constituents (Houtzager 2000). In contrast, Nang Rong exhibits a traditional form of relatively flat political relations, vesting little power in village headmen. The hierarchical relations that exist are based instead on age and gender (Phongphit and Hewison 2001). These are among the slowest of all the endogenous processes we consider (Figure 3.4), and among the most important for health. While the implementation of a particular policy or government agency may occur rapidly, the process of garnering support for, lobbying, and designing it is usually slow. Even local governance structures, formal or informal, change only over the span of decades. We have yet to study the development of local basic healthcare provision in our study areas, in part because of the slowness of the process. We can point to healthcare as one of the top two (along with education) reasons for moving among migrants from the countryside to the city in Altamira and Santarém. Anecdotally, we can point to the reported importance of healthcare facilities (among other types) in the success of Lucas do Rio Verde in attracting businesses and workers, and to the reported struggles of local healthcare workers in getting more supplies, personnel and equipment in Santarém. These processes, however, are essential for the ability of a household to invest in both preventative medicine and treatment, and therefore the HC of its members.

Environmental factors

Like political factors, environmental factors may change quickly following a long process of endogenous change. Global changes in greenhouse gases may trigger rapid climate change, but the buildup to that point may take decades or longer. At the local level, deforestation and withdrawals of water for domestic and agricultural use can change regional climate on a similarly long time scale. In Altamira, deforestation near the city led in less than a generation to a warmer and drier climate in that area than in regions just 100–200 kilometers west. Farmers attribute drying up of favorite fishing holes, for example, to increased frequency of flash precipitation that exceeds percolation capacity and simply runs off the landscape. Collective agreements to protect forest in the interest of protecting rainfall (and also to strengthen indigenous groups) led to the so-called Terra do Meio south of Altamira remaining forested from the 1970s until very recently, without formal protected status. Within the past decade, loggers and settlers have encroached on this intact forest, generating frequent conflicts, a strong forest protection movement, and formal designation of most of the region as protected or indigenous lands. This history provides a clear example of the circular relation between livelihood decisions and environmental and political change. Over shorter time-scales, the land-use component of the livelihood strategies can affect surface water quality and availability for other residents on the frontier. In extreme cases, the construction of bunds or other water diversion systems for rice production can leave downslope neighbors with insufficient or polluted water for their own fields, interactively driving the development of new political and social institutions. Each development alters inputs to the decision-making of frontier residents about land use and the benefits of on-farm or off-farm activities.

Discussion*Interactions among health, capitals, and livelihoods*

We describe above investments in health as a form of human capital, and turn now to the role of health shocks in our framework. It is well-known that greater household capacity to invest in health results from (usually) growing stocks of capital while resilience to shocks, including health problems, may be attained through more diversified capital portfolios (Ellis 1993). In some situations, however, a health shock or long-term illness can create a downward “vicious circle” (White *et al.* 2005). Households may deplete household assets to cope with costs of treatment (e.g. food, medication, transportation, and the shadow price of absent labor), which reduces their ability to maintain the health of other members and of the overall household unit. Depletion can come both in terms of the absolute reduction of capitals in various classes and in terms of the diversity of a household’s portfolio, which when reduced may further increase that household’s overall vulnerability.

Our approach is distinguished from previous literature in this area by a focus on the interplay between household strategies and evolving context in frontiers,

which leads to stage-specific predictions about the order in which the five capitals will be depleted in response to an ill-health event. Our predictions are summarized in Figure 3.5 and compared with predictions made by Sauerborn *et al.* (1996). These draw on the changing relative returns to, and therefore investment preferences for, each form of capital (shown in Figure 3.3), the representation of the capital in portfolios, and the exchangeability of the different forms of capital. Representation in portfolios and exchangeability determine whether a capital can be used to meet needs during an ill-health event while investment preferences determine the results of foregone investment opportunities for a household. FC is the first depleted in any illness because of its exchangeability for healthcare costs both direct and indirect.

While the FC is being depleted, households will forego investments in other forms of capital (rather than using up other capitals). In the early stages of frontier development, households are investing in PC, SC and HC, and foregoing these investments will leave them with little to draw on as contexts change. PC may be depleted if it can be exchanged (e.g. chainsaws, tractors), and HC will then be converted to money for care through negative investments in HC (healthy family members working until ill). Households are then left with the NC and SC they arrived with. The NC and SC (mostly bonding) are both declining in returns. These may be used to obtain FC if possible, but this action usually signals the departure of the household from the area as they sell the farm and overdraw their social ties. Thus, early in frontier development, we posit strong pattern of preserving social and natural capital. These predictions for the initial phases of

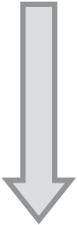
Order of depletion	Sauerborn <i>et al.</i> 1996	Initial stage	Post-frontier
<p>First depletion</p>  <p>Last depletion</p>	Financial capital	Financial capital	Financial capital
	Physical capital	Physical capital	Physical capital
	Human capital	Human capital	Human capital
	Social capital	Social capital	Social capital
	Natural capital	Natural capital	Natural capital
<p>Note: Cells of the same color indicate roughly equivalent degrees of hardship in depleting each type of capital. Darker cells indicate increasing hardship.</p>			

Figure 3.5 Order of capital depletion during illness episode as frontiers evolve.

frontier evolution, when natural capital is plentiful and essential to guaranteeing household well-being, map closely onto the empirical observations made in previous studies examining the African Sahel (Adams *et al.* 1998).

In post-frontier contexts, households initially are more resilient because they have diversified capital portfolios and larger stocks of capital. They are heavily investing in PC, HC, and SC for the acquisition of the most exchangeable FC. As in other settings, illness will initially lead to a depletion of FC because of its ready acceptance as payment. It will also result in households foregoing investments in PC, HC, and SC. Next to be depleted will be PC, because of its higher level of exchangeability in the new context. With the presence of land, credit and product markets, higher stocks of PC such as vehicles, machinery, housing, and live-stock can be converted into cash for healthcare through sale, mortgage, or rental. Because of the much lower returns to NC and the presence of these markets, NC is next to be depleted, leaving households with HC and SC. In post-frontier contexts, sprawling networks of bridging ties link households to temporary housing in urban areas (near health centers), migrant remittances, and political officials, all of which become important to strategies for combating illness (Padoch *et al.* 2008). Depending on the length of illness, HC and SC may be enough to regain capital stocks after an illness, as education and social connections will help household members get good jobs, pay the rent, and save money for purchase of land, or other NC or PC. With long-standing illness, or illness that affects households during critical years of investment in HC or SC, foregone investments may limit the accumulation of HC and SC and lead to a downward spiral. Successive ill-health events not only deplete household resources to dangerous levels, but tend to drive household capital portfolios closer to the characteristics they displayed earlier in the frontier. With the depletion of FC and PC, and sometimes NC, households' capital portfolios resemble (though with different forms of HC and SC) those of frontier settlers, and they may become settlers in new frontiers elsewhere.

Conclusions

In frontier settings, as well as low-income settings generally, avoiding a vicious circle may depend on interventions, such as provision of health services or subsidized transportation to reduce transportation cost (Russell and Gilson 2006). In our Brazilian study areas, multi-local households (those maintaining multiple residences in different regions) attempt to benefit from proximity to health services in urban areas, while maintaining control over NC and SC on the frontier (Padoch *et al.* 2008). This duality is facilitated by effective and affordable (subsidized for the elderly) bus transport. In this sense, free health services leverage households' productivity by providing low cost investments in human capital (Grossman 1998) and by removing the need for households to finance health expenses through depleting other capitals.

As a result, the provision of free or low-cost healthcare in poorly developed settings like the smallholder frontiers we describe can be seen to reduce necessary expenditures and free up household capitals for other investments (Russell and Gilson 2006). With this application of our theory, we have described the sorts of

capital likely to be available to households in a frontier and what sorts of investments are likely in response to decreasing the cost of healthcare (as well as likely patterns of depletion from increasing cost of care). In early frontier settings, few capitals are available and the lack of affordable and available healthcare leads to out-migration as households must spend the SC and NC available to them, a lesson learned in Altamira with early high rates of malaria and out-migration (Moran *et al.* 2005). In post-frontiers, investments in subsidized transport for healthcare and in inexpensive care facilitate more rapid increases in HC and SC, and the failure to provide such care leads to stalled development (households reverting to early frontier capital portfolios) and rapid turnover in land ownership if markets exist for land.

The politics of health have traditionally focused on equitable health supply, based on technical and scientific intervention in unassisted or under-covered areas, which are key, given the importance of accessibility in household decision-making. Yet the development of markets and increased accessibility independent of directly targeted healthcare policy can have the same impact (as in the dual-residence households). This mixed approach is likely to benefit a wider group of households, addressing issues of equity and human rights in the process. We argue that a sustainable approach to long-term improvement of productive capacity of households can facilitate both health investments and the diversification of capital portfolios, ultimately improving both health and overall well-being (Hampshire *et al.* 2009).

References

- Adams, R.T. (2008) Large-scale mechanized soybean farmers in Amazônia: new ways of experiencing land. *Culture and Agriculture* 30: 32–37.
- Adams, A., Cekan, J., and Sauerborn, R. (1998) Towards a conceptual framework of household coping: reflections from rural west Africa. *Africa: Journal of the International African Institute* 68: 263–283.
- Alva, S. and Entwisle, B. (2002) Employment transitions in an era of change in Thailand. *Journal of Southeast Asian Studies* 40: 303–326.
- Alvi, E. and Dendir, S. (2009) Private transfers, informal loans and risk sharing among poor urban households in Ethiopia. *Journal of Development Studies* 45: 1325–1343.
- Arima, E.Y., Walker, R.T., Perz, S.G., and Caldas, M. (2005) Loggers and forest fragmentation: behavioral models of road building in the Amazon basin. *Annals of the Association of American Geographers* 95: 525–541.
- Axinn, W.G., Barber, J.S., and Biddlecom, A.E. (2010) Social organization and the transition from direct to indirect consumption. *Social Science Research* 39: 357–368.
- Batterman, S., Eisenberg, J., Hardin, R., Kruk, M.E., Lemos, M.C., Michalak, A.M., Mukherjee, B., Renne, E., Stein, H., Watkins, C., and Wilson, M.L. (2009) Sustainable control of water-related infectious diseases: a review and proposal for interdisciplinary health-based systems research. *Environmental Health Perspectives* 117: 1023–1032.
- Bebbington, A. (1999) Capitals and capabilities: a framework for analyzing peasant viability, rural livelihoods and poverty. *World Development* 27: 2021–2044.
- Becker, G.S. (2007) Health as human capital: synthesis and extensions. *Oxford Economic Papers* 59: 379–410.
- Berman, E., Bound, J., and Griliches, Z. (1994) Changes in the demand for skilled labor within US manufacturing industries: evidence from the annual survey of manufacturing. *Quarterly Journal of Economics* 2: 367–397.

- Bilsborrow, R.E. (2002) Migration, population change and the rural environment. *Environmental Change and Security Report* 8: 69–94.
- Blaikie, P. and Brookfield, H. (1987) *Land Degradation and Society*. London, UK: Methuen.
- Boucher, S. and Guirking, C. (2007) Risk, wealth and sectoral choice in rural credit market. *American Journal of Agricultural Economics* 89: 991–1004.
- Curran, S.R. and de Sherbinin, A. (2004) Completing the picture: the challenges of bringing “consumption” into the population-environment equation. *Population and Environment* 26: 107–131.
- Curran, S.R., Chung, C.Y., Cadge, W., and Varangrat, A. (2004) Educational opportunities for boys and girls in Thailand. *Review of Sociology of Education* 14: 59–102.
- Curran, S.R., Garip, F. Chung, C.Y., and Tangchonlatip, K. (2005) Gendered migrant social capital: evidence from Thailand. *Social Forces* 84: 225–255.
- DAntona, A.O., VanWey, L.K., and Hayashi, C.M. (2006) Property size and land cover change in the Brazilian Amazon. *Population and Environment* 27: 373–396.
- DAntona, A.O. and VanWey, L.K. (2007) Estratégias para amostragem da população e da paisagem em pesquisas sobre uso e cobertura da terra. [A strategy for sampling the population and the landscape in research on land use and land cover.] *REBEP (Revista Brasileira De Estudos De População)* 24: 263–275.
- David, H.P. and Viravaidya, M. (1986) Community development and fertility management in rural Thailand. *International Family Planning Perspectives*, 12: 8–11.
- de Sherbinin, A., VanWey, L., McSweeney, K., Aggarwal, R., Barbieri, A., Henry, S., Hunter, L.M., and Twine, W. (2008) Rural household demographics, livelihoods and the environment. *Global Environmental Change-Human and Policy Dimensions* 18: 38–53.
- Eisenberg, J.N.S., Desai, M.A., Levy, K., Bates, S.J., Liang, S., Naumoff, K., and Scott, J.C. (2007) Environmental determinants of infectious disease: a framework for tracking causal links and guiding public health research. *Environmental Health Perspectives* 115: 1216–1223.
- Ellis, F. (1993) *Peasant Economics: Farm households and agrarian development*, 2nd edition. Cambridge, UK: Cambridge University Press.
- Ellis, F. (1998) Household strategies and rural livelihood diversification. *Journal of Development Studies* 35: 1–38.
- Entwisle, B., Rindfuss, R.R., Guilkey D.K., Chamrathirong, A., Curran, S.R., and Sawangdee, Y. (1996) Community and contraceptive choice in rural Thailand: a case study of Nang Rong. *Demography* 33: 1–11.
- Entwisle, B., Walsh, S.J., Rindfuss, R.R., and VanWey, L.K. (2005) Population and upland crop production in Nang Rong, Thailand. *Population and Environment* 26: 449–470.
- Entwisle, B., Rindfuss, R.R., Walsh, S.J., and Page, P.H. (2008) Population growth and its spatial distribution as factors in the deforestation of Nang Rong, Thailand. *Geoforum* 39: 879–897.
- Futemma, C. and Brondizio, E.S. (2003) Land reform and land-use changes in the lower Amazon: implications for agricultural intensification. *Human Ecology* 31: 369–402.
- Grossman, M. (1972) On the concept of health capital and the demand for health. *Journal of Political Economy* 80: 223–255.
- Grossman, M. (1999) *The Human Capital Model and the Demand for Health*. NBER Working Paper 7078. Cambridge, MA: National Bureau of Economic Research.
- Hampshire, K.R., Panter-Brick, C., Kilpatrick, K., and Casiday, R.E. (2009) Saving lives, preserving livelihoods: understanding risk, decision-making and child health in a food crisis. *Social Science and Medicine* 68: 758–765.

- Hayward, M.D. and Gorman, B.K. (2004) The long arm of childhood: the influence of early-life social conditions on men's mortality. *Demography* 41: 87–107.
- Houtzager, P.P. (2000) Social movements amidst democratic transitions: lessons from the Brazilian countryside. *Journal of Development Studies* 36: 59–88.
- Hull, J.R. (2008) Migration, remittances, and monetization of farm labor in subsistence sending areas. *Asian and Pacific Migration Journal* 16: 451–484.
- Jepson, W. (2006) Private agricultural colonization on a Brazilian frontier, 1970–1980. *Journal of Historical Geography* 32: 839–863.
- Joffe, M. (2007) Health, livelihoods, and nutrition in low-income rural systems. *Food and Nutrition Bulletin* 28: S227–S236.
- Keyes, C. (1976) In search of land: Village formation in the central chi river valley, north-eastern Thailand. *Contributions to Asian Studies* 9: 45–63.
- Korinek, K., Entwisle, B., and Jampaklay, A. (2005) Through thick and thin: Layers of social ties and urban settlement among Thai migrants. *American Sociological Review* 70: 779–800.
- Lambin, E.F., Geist, H.J., and Lepers, E. (2003) Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources* 28: 205–241.
- Ludewigs, T. (2002) Agricultural credit and the build-up of social capital in the Brazilian Amazon Frontier. Institutional Analysis and Development Mini-Conference, 2002. See www.indiana.edu/~workshop/seminars/papers/y673_fall_2002_ludewigs.pdf (accessed 7 July 2012).
- McCracken, S.D., Siqueira, A.D., Moran, E.F., and Brondizio, E.S. (2002) Land use patterns on an agricultural frontier in Brazil: insights and examples from a demographic perspective. In *Deforestation and Land Use in the Amazon*, C.H. Wood and R. Porro (eds). Gainesville, FL: University Press of Florida, 162–192.
- McCusker, B. and Carr, E.R. (2006) The co-production of livelihoods and land use change: case studies from south Africa and Ghana. *Geoforum* 37: 790–804.
- Moran, E.F. (1981) *Developing the Amazon*. Bloomington, IN: Indiana University Press.
- Moran, E.F. (2010) *Environmental Social Science: Human Environment Interactions and Sustainability*. Malden, MA: Wiley-Blackwell.
- Moran, E.F., Brondizio, E.S., and McCracken, S.D. (2002) Trajectories of land use: Soils, succession, and crop choice. In *Deforestation and Land Use in the Amazon*, C.H. Wood and R. Porro (eds). Gainesville: University of Florida Press, 193–217.
- Moran, E.F., Brondizio, E.S., and VanWey, L.K. (2005) Population and environment in Amazonia: landscape and household dynamics. In *Population, Land Use, and Environment: Research Directions*, B. Entwisle and P. Stern (eds). Washington, DC: National Academies Press, 106–134.
- Padoch, C., Brondizio, E., Costa, S., Pinedo-Vasquez, M., Sears, R.R., and Siqueira, A. (2008) Urban forest and rural cities: multi-sited households, consumption patterns, and forest resources in Amazonia. *Ecology and Society* 13: 2.
- Perz, S.G., Caldas, M.M., Arima, E., and Walker, R.J. (2007) Unofficial road building in the Amazon: socioeconomic and biophysical explanations. *Development and Change* 38: 529–551.
- Phongphit, S. and Hewison, K. (2001) *Village Life: Culture and Transition in Thailand's Northeast*. Bangkok, Thailand: White Lotus.
- Piotrowski, M. (2006) The effect of social networks at origin communities on migrant remittances: evidence from Nang Rong District. *European Journal of Population* 22: 67–94.
- Piotrowski, M. (2009) Migrant remittances and skipped generation households: investigating the exchange motive using evidence from Nang Rong, Thailand. *Asian and Pacific Migration Journal* 18: 163–196.

- Reardon, T. and Vosti, S.A. (1995) Links between rural poverty and the environment in developing countries: asset categories and investment poverty. *World Development* 23: 1495–1506.
- Rigg, J. (1987) Forces and influences behind the development of upland cash cropping in Northeast Thailand. *Geographical Journal* 153: 370–382.
- Rindfuss, R.R., Piotrowski, M., Thongthai, V., and Prasartkul, P. (2007) Measuring housing quality in the absence of a monetized real estate market. *Population Studies* 61: 35–52.
- Rindfuss, R., Entwisle, B., and Walsh, S. (2009) Nang Rong Projects [Thailand]. Computer file. Ann Arbor, MI: Inter-University Consortium for Political and Social Research.
- Russell, S. (2004) The economic burden of illness for households in developing countries: a review of studies focusing on malaria, tuberculosis, and human immunodeficiency virus/acquired immunodeficiency syndrome. *American Journal of Tropical Medicine and Hygiene* 71: 147–155.
- Russell, S. and Gilson, L. (2006) Are health services protecting the livelihoods of the urban poor in Sri Lanka? Findings from two low-income areas of Colombo. *Social Science and Medicine* 63: 1732–1744.
- Sauerborn, R., Adams, A., and Hien, M. (1996) Household strategies to cope with the economic costs of illness. *Social Science and Medicine* 43: 291–301.
- Saxena, N.C., Speich, N., and Steele, P. (2005) *Review of the Poverty—Environment Links Relevant to the IUCN Programme*. Gland, Switzerland: IUCN.
- Smith, K.P. and Christakis, N. (2008). Social networks and health. *Annual Review of Sociology* 34: 405–429.
- Steward, C. (2007) From colonization to “environmental soy”: A case study of environmental and socio-economic valuation in the Amazon soy frontier. *Agriculture and Human Values* 24: 107–122.
- VanWey, L.K., D’Antona, A.O., and Brondizio, E.S. (2007) Household demographic change and land use. *Population and Environment* 28: 163–185.
- VanWey, L.K., D’Antona, A.O., and Guedes, G.R. (2008) Land Use Trajectories after Migration and Land Turnover, New Orleans, LA. Annual Meeting of the Population Association of America, New Orleans, LA, 17–19 April.
- VanWey, L.K., Guedes, G.R., and D’Antona, A.O. (2009) Out-migration and household land use change in Altamira, Pará, Marrakech, Morocco. Proceedings of the XXVI International Population Conference, Marrakech, Morocco, 27 September–2 October. See <http://iussp2009.princeton.edu/download.aspx?submissionId=93059> (accessed 7 July 2012).
- Walker, R., Moran, E., and Anselin, L. (2000) Deforestation and cattle ranching in the Brazilian Amazon: external capital and household processes. *World Development* 28: 683–699.
- Walsh, S.J., Rindfuss, R.R., Prasartkul, P., Entwisle, B., and Chamratrithong, A. (2005) Population change and landscape dynamics: Nang Rong studies. In *Population, Land Use, and Environment: Research Directions*. B. Entwisle and P.C. Stern (eds). Washington, DC: National Academy Press, 135–162.
- White, P.J., Ward, H., Cassell, J.A., Mercer, C.H., and Garnett, G.P. (2005) Vicious and virtuous circles in the dynamics of infectious disease and the provision of health care: gonorrhoea in Britain as an example. *Journal of Infectious Disease* 192: 824–836.
- Woolcock, M. and Narayan, D. (2000) Social capital: implications for development theory, research, and policy. *World Bank Research Observer* 15: 225–249.