# Microdemography and the Environment: Household Composition and Lifecycles Mediating Livelihoods, Deforestation and Land Use in the Amazon

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**Abstract.** Deforestation, poverty, land conflicts and the expansion of infrastructure and economic activities in the Amazon have increased concerned about the fate of the largest and more biodiverse forest in the world. Few studies however have investigated the role of the household demographic dynamics on these landscape changes and over the wellbeing of Amazonian populations. Nonetheless, complex patterns of demographic and socioeconomic change reflect a diversity of factors such as globalization, expansion of international market-oriented activities, infrastructure building and migration networks. This paper uses a microlevel approach to show how demographic change mediates farm household transitions over the lifecycles as well as livelihoods composition over distinct stages of frontier development. We review the extant literature to propose a theoretical framework of microdemography of rural and frontier areas, and test it based upon an empirical analysis of a twenty-five years panel of plots and households in the municipality of Machadinho, Brazilian Amazon. I use descriptive and multivariate statistics (Principal Components Analysis and Multiple Linear Regression) and land use classification to identify profiles of demographic composition and lifecycles over stages of frontier development, and associate them with specific household strategies and combinations capitals (human, financial, physical, natural and social) which define household livelihoods. The results provide evidences to advance a theoretical a framework integrating a set of theories focusing at the household level and which unveil how demographic dynamics (specifically in terms of household composition and lifecycles) mediates livelihoods, including land use changes and deforestation, over the development stages of frontier development.

**Keywords.** Microdemography, household composition and lifecycles, livelihoods, capabilities, multiphasic responses, land use and deforestation, Amazon,

## Introduction

This paper proposes a theoretical framework to integrate a set of theories at the household that unveils how demographic dynamics (specifically in terms of household composition and lifecycles) mediates livelihoods over different stages of development in rural frontiers as well as in rural areas with a degree of integration to urban areas. From a broader perspective, these theories recognize the importance of the context (the macro scale) assuming different meanings at each stage of the frontier development when a diversity of factors such as globalization, expansion of international market-oriented activities, infrastructure building, and migration networks play different roles, affecting internal and international migration and labor mobility.

I review the extant literature and suggest the need to better frame and unveil the nexus between demographic dynamics at the microscale (individuals and households), livelihoods, household and land use life cycles as well as demographic and land use responses to contextual changes at different stages of frontier development (see previous discussion in Barbieri et al., 2005; Barbieri, 2006; Barbieri et al. 2009a; Barbieri and Pan, 2013). These theories are particularly useful to understand the many components of colonist's decision-making, individual aspirations of income and wellbeing, collective needs of familial groups in rural settings, and the context (community, region, nation) in which household decisions are made

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(Sherbinin et al., 2008). However, they do not adequately discuss how these factors may simultaneously connect distinct livelihood strategies according to changes in household lifecycles and composition over time as well as contextual changes, as depictured by stages of frontier development.

I propose a theoretical framework and test it through the empirical analysis of a unique longitudinal dataset for the municipality of Machadinho, in the Southwestern Brazilian Amazon. I tracked land use/cover change and household decision-making processes as the agricultural frontier evolved from pioneer (initial settlement) to a market-oriented frontier. There are two reasons to choose Machadinho. First, it is within the most dynamic area of occupation by migrant colonists in the Amazon (through cattle ranching, agribusiness, and infrastructure building such as roads and hydroelectric plants), with corresponding drastic land use changes linked to conversion of primary forest. Second, its occupation has been documented and surveyed over twenty five years (from 1985 to 2010). To the extent of our knowledge, this is the only study area in the Amazon with quality survey data for the same plots and households since the very onset of occupation and tracked for so long, capturing all distinct stages of frontier settlement from a population and environmental perspective. Because of the uniqueness of the data gathered over the years, I was able to test the theoretical framework and provide evidences to understand the linkages between demographics, livelihoods, household and land use cycles and stages of frontier settlement.

Besides this introduction, I organize this paper in six sections. The second provides a review of the literature on frontier development phases and microdemographic theories that will ground, in the following section, my proposal of a integrated theoretical framework. The fourth section describes the study area in the Brazilian Amazon – the municipality of Machadinho D' Oeste. It follows a description of the methods that will test the proposed theoretical framework-descriptive and multivariate statistics (Principal Components Analysis and Multiple Linear Regression) and land use classification. The last two sections bring the results and an overall discussion and conclusions of the paper.

## Microdemography of frontier areas

### Stages of frontier development

As in many other conceptual frameworks, agriculture frontiers evolve in phases towards progressive market integration (Caldas et al. 2007, Walker 2004). For instance, in a review of the literature on settler´s colonization of frontier areas in Latin America, Marquette (2006) suggests that frontiers evolve through three different phases: from *adaptatio*n (first three years based on subsistence agriculture and hardship in terms of living conditions), to an *experimentation phase* (five to ten years when farm household start to diversify land uses and create adaptation mechanisms to the local environment), and finally the *consolidation phase* (when land use diversification reaches higher efficiency levels and generate higher wellbeing for colonists and new settlers).

In each of these phases, the connection of the household with macro contextual factors may change, allowing households to articulate their connections to certain hierarchical scales while disarticulated of others (Browder and Godfrey 1997; Brondízio 2008). For example, growing urbanization change household livelihoods at the same time that increasing access to markets and population ageing may factor land use changes towards less labor-intensive and profitable activities, such as cattle ranching. Rural-urban connections are more than a simple spatial concept; it represents the space where social relations operate facilitating flows of information, technology, work, and money (Summers 2008). Therefore, the way the relation between the rural and the urban develops allows understanding how local farmers interact with the environment beyond the frontier boundaries (Monte-Mór 2004).

This non-linear dynamics of frontier development, and to a certain extent, of the property (plot), implies that contextual factors such as the social profile of farmers, settlement

history, and the connection networks of the frontier with other frontiers and markets, determine the characteristics and the pace of change in each phase (VanWey et al. 2012; Summers 2008). Although some frontiers may experience boom-and-bust cycles of development – from intense deforestation to land abandonment – there is a general trend of change in the economic environment of the frontier from subsistence to an increasing articulation with markets (Walker 2004). This implies that the influence of household life cycle factors on land use change and livelihood strategies decrease as frontier integrates into markets over time. At the same time, the more articulated the frontier with higher level economic forces (national and global markets) the less household demography is able to explain change in local landscape (Barbieri et al., 2005).

Although at a later frontier stage farmers may become market-oriented (as in Caldas et al. 2007), they continue to derive livelihood from subsistence or market-oriented agriculture. This is the basic difference between smallholders and large capitalist farmers in post-frontier scenario (Ellis 1993; Browder & Godfrey 1997). Evidences from different agricultural frontiers in the Amazon support this view. Although in some areas the share of agricultural production sold in the market reaches over 80%, an important part of this production is used for meeting immediate consumption needs of the household members (Marquette 1998; Walker et al. 2002; VanWey et al. 2007).

As the frontier evolves over time, intra-frontier mobility becomes more important (Barbieri and Pan, 2013; Barbieri et al., 2009a). The literature on population mobility in post-frontiers areas has increasingly given attention to factors at aggregate levels immediately above individuals and households – i.e., communities and villages. In this regard, socioeconomic and institutional factors mediating mobility decisions can include, for example, the segmentation of labor markets, policies fostering the opening of roads, inadequate credit or titling policies, and other social, cultural, and politico-institutional factors. Overall, population mobility in the evolving frontier scenario is a result of complex forces acting at different scales and pace over frontier development: (1) household demographic dynamics affected by the advancement of demographic transition and population ageing in the frontier and their impact on land use choices and farm composition (particularly age and farm labor composition), as predicted by household life cycle theories (Ellis 1993, Sherbinin et al 2008, Walker et al. 2002; (2) a growing connectivity of rural-urban areas through migration of selected family members, dual-residency, and growing market-oriented land use systems, as predicted by bit-rent models (Hoselitz 1963, Andersen et al. 2002), and, (3) institutional changes - both political and economic, affecting farmers' perceived returns to their capital stocks, as predicted by the political economy perspective (Sawyer 1984, VanWey et al. 2013).

*Theories on household demographic dynamics, livelihoods and land use in frontier settings*

The relationship between demographic dynamics, livelihoods and land use strategies may be explained by three theoretical approaches: *household and land use life cycle, livelihood and capabilities approach,* and the *revisited theory of multiphasic responses*. On the aggregate these theories, focusing at the household level, explain the connections among demographic composition and evolution, many components of colonist´s decision-making, individual aspirations of income and welfare, collective needs of familial group(s) in rural settings, and the context (community, region, nation) in which these decisions are made.

The *Household and Land Use Life Cycle approach* can be examined by drawing upon Chayanov's peasant cycle (Thorner *et al.* 1986; Ellis 1988), as adapted by several authors to the Amazonian context (e.g., (see, e.g., Thorner *et al.* 1986; Walker and Homma 1996; Marquette 1998; McCracken *et al.* 2002; Perz 2001, Walker *et al.* 2002; Moran *et al.* 2003; Barbieri et al., 2005; Caldas et al., 2007; Sherbinin et al 2008) and livelihood approaches (see, e.g., Ellis 1988; Bebbington, 1999; Sherbinin et al 2008; VanWey et al. 2012a; Guedes et al. 2012). The Russian economist, A.V. Chayanov, established a relationship between the demographic characteristics of farm households and agricultural land use in the years following the Russian Revolution in 1917. Chayanov stated that "demographic differentiation", defined by age of the head of the

household and the household ratio of producers to consumers (estimated from the number of children, adults, and elders) influences the amount of cultivated land (see Thorner, 1986; Ellis, 1988). A basic assumption in Chayanov's model is that changes in household size and composition (specifically, the ratio of consumers to workers in the household) ultimately determines a household's decision on how to maximize utility in terms of allocating labor to farm production or to leisure, since farm labor is associated with drudgery or irksomeness (Ellis, 1988).

The combination of individual life-cycle characteristics in the household conditions the degree of pressure on agricultural production (Pichón, 1997; Marquette 1998; McCracken *et al.*, 2002; Pichón and Bilsborrow 1999). The main argument is that changes in household size and composition affect land use and farm household labor allocation, and that evidently out-migration and other types of mobility directly affects household size and composition. In periods of low household labor availability (e.g., early in the family life cycle when couples have young children, as well as later when adult sons or daughters marry and move away), households tend to adopt agricultural practices suitable to the low availability of labor, such as clearing little forest and raising annual crops, in the first case, or switching land use to cattle, in the second. The effect of the number of adults in the household on out-migration or commuting of a member can be positive or negative, depending, for example, on the amount of farm land available. A small amount of land will lead to decreasing returns to labor, as household size increases, favoring out-migration. On the other hand, a large farm will result in a high ratio of land to labor even with a large household, so the returns to labor may remain high even with the addition of a new adult or the aging over time of a child to becoming an adult in the household.

As households accumulate some capital over time, and have a higher availability of labor (viz., young children becoming teenage children or young adults), they usually shift land use from annual crops increasingly to cash crops and pasture. As young adults leave the household as a rite of passage or to take advantage of employment opportunities elsewhere, farmers switch to less labor-intensive forms of land use, notably pasture. However, to the extent that such a process is under way autonomously, that is, over time farmers seek to acquire cattle for other reasons, this will free up labor, which facilitates out-migration of circular mobility (off-farm employment). Remittances sent by household migrants, in turn, may be invested on farm activities, particularly cattle given the dearth of labor.

*Household Livelihoods and Capabilities* approach allow conceptualizing households as units of (mainly agricultural) production and consumption. Households are able to use strategies towards a certain income and welfare levels through a portfolio combining distinct assets or capitals, which are accumulated over time. Household composition of capitals can change over time due to contextual factors, constrains, and opportunities at different stages of frontier development. Following Bebbington (1999), Sherbinin et al. (2008) emphasize five different types of capitals: natural, social, human, physical, and financial. VanWey et al. (2012b) suggest that the overall level of capitals are important for long term response to stress, while the capital composition smooths consumption in short term shocks thus being a risk-minimizing mechanism. Furthermore, the sequence of capital depletion varies as returns to capital shift over frontier development.

From this perspective, poverty in rural areas can be interpreted as the inability of rural households to select the portfolio of capitals that fights exogenous threats to their permanent well-being. Poverty and rural well-being on rural populations is defined as i) the general lack of choices and opportunities that are reflected in low levels of income, portfolio of assets, land use choices, land tenure security, access to natural resources, and social networks (Guedes et al., 2014), ii) a direct function of both the level (composition) and return (utility) to capitals and as an indirect product of exogenous constraints set up at higher scales - both temporal and spatial (Reardon and Vosti 1995; Murphy 2001; Wunder 2001; German 2003; Caviglia-Harris and Sills 2005; Kay 2006; Guedes et al. 2012), ii) the level of material satisfaction provided by certain livelihood strategies representing a specific portfolio of capitals (financial and non-financial) structured and modified by their ability to increase household's satisfaction (Bebbington 1999).

Regarding the third definition, capital levels define rural dimensions of wellbeing on the conceptual *rural livelihood framework* discussed by Sherbinin et al. (2008). The authors emphasize five different types of capital: a) *"Natural capital: the natural resource stock, or local environmental endowment (including water, wind, soil, forest resources); b) Social capital: social resources, such as interpersonal networks, membership in groups, relationships of trust, access to wider institutions of society; c) Human capital: including formal and informal education, local ecological knowledge, the ability to work, and good health; d) Physical capital: including productive assets held by the household (land, tools, oxen) as well as communal assets to which they have access (roads, communication infrastructure such as radio broadcasts); e) Financial capital: typically, the most fungible of assets, including cash savings, supplies of credit, or regular remittances and pensions."*

Still according to the authors, the portfolio of some combination of these assets defines a household livelihood strategy. Capitals are accumulated over time and are shaped by contextual factors such as social, cultural, political, and economic opportunities and constraints. As the frontier evolves over time, the individual and household characteristics and motivations shape new livelihood strategies given the contextual opportunities and constrains. VanWey et al. (2013), based on Bebbington´s (1999) approach to multiple capitals, suggest that farmers´ livelihoods trajectories over frontier development change as response to returns to farmers' capital portfolio over frontier development. Households' decisions are also conditioned by the livelihood decisions of agents, the broad portfolio of assets controlled by the agents, the subjective and context-specific returns to different types of capitals, and the evolving multidimensional context. As a matter of fact, Bebbington (1999) suggests that besides access to capitals and their different combinations to achieve desired welfare and subsistence needs, households can expand their access to capitals through different forms of interaction with the State markets and the society as a whole.

As observed in other contexts (see, e.g., Barbieri et al., 2005), livelihood decisions which involve distinct mobility strategies (labor circulation for off-farm employment, internal and international migration) may become a key aspect of the household strategies to change portfolio towards a higher prevalence of financial and social capital vis-a-vis capitals more related to on-farm production (physical, natural, and some components of the financial capital). These are in fact key capitals favoring the acquisition and maximization of the benefits of mobility, such as remittances and off-farm income (financial capital) and migration networks (a component of social capital) which decreases the costs of migrations and facilitates labor accessibility in potential places of destination.

As a reaction to larger sociopolitical and economic transformations, small-scale producers have been increasingly involved in off-farm activities (Murphy 2001; Perz 2005). In this context, migration or circulation of family members to urban or other rural areas and the formation of multigenerational, and multi-sited rural-urban households have also been common strategies adopted to generate income and bring about economic diversification (Barbieri *et al*. 2009b). Following de Haan (1999, p. 13), "keeping a foot on the farm, in which migration is part of a 'diversification' strategy is perhaps the most common motive". Farm household and lifecycle factors are thus more useful to explain mobility patters within the frontier, together with macro level approaches such as the historical structuralism (particularly the political economy) factors that place migration into the initial frontier settlement as the result of infrastructure expansion and the transformation of the production structure in origin areas (Barbieri, 2006; Caviglia-Harris et al., 2013).

Household motivations to adopt land extensification or intensification, as well as mobility or some type of fertility control, are addressed by a comprehensive model suggested by Bilsborrow (1987), built upon Davis' (1963) *Theory of the Multiphasic Response*. In the original formulation by Davis (1963), the "Theory of the Multiphasic Response" explains how family decisions to migrate or change fertility behavior are alternative responses to population pressures on limited resources. Based on the experience of the 1940s-1950s industrializing Japan and Europe, Davis suggested that the decline in mortality, sustained natural increase and

the consequent population pressures on land are a powerful stimulus for families to control fertility through demographic responses, such as marriage postponement, contraception, sterilization, abortion and, as a last resource, migration outward (if the other responses proved inadequate). Motivations to adopt one response or a combination of responses are linked to the fact that families associate population growth with the loss of opportunities to maximize status and welfare. Responses are concurrent (or "multiphasic"), in the sense that households can adopt responses simultaneously as a result of population pressures, and the higher the prevalence of one type of response and the higher its effectiveness in relieving negative pressures on living standards, the less likely other responses are to occur (Bilsborrow, 1987).

Bilsborrow (1987), Bilsborrow and Ogendo (1992) and Bilsborrow and Geores (1994) suggest that the Theory of the Multiphasic Response as proposed by Davis (1963) is not adequate to consider the effects of nondemographic responses in the face of threats to living standards in rural areas, which include the application of a new technology in the agricultural system and the extension of the land area under cultivation. Bilsborrow suggests that demographic responses represented by the change in the fertility behavior and nuptiality tend to be a last alternative due to fertility being a result of complex cultural factors. Even considering the concurrent, or "multiphasic" adoption of responses – with farm households choosing a "portfolio" of different options, which can include, for example, a mix or intensification, extensification and off-farm employment of one household member – families usually first try economic responses related to land management, such as land intensification and extensification. Land intensification tends to reduce out-migration pressures, while extensification can induce short-range mobility (lands within the same rural community, or even in the family's plot of land) or to "open access" lands (Bilsborrow, 2002). If in a first moment the economic responses accommodate the pressures of growing population, they can negatively affect the sustainability of agricultural practices given population growth and pressure over limited resources (for example, land overuse causing loss of soil fertility and erosion). Out-migration is an economic-demographic response that follows as a likely alternative to diversify household income. Fertility regulation, a demographic response, is usually the last response and involves measures such as postponement of marriage or a reduction in marital fertility[2]. Nonetheless, the greater the response of one type, the less pressure there is for the other responses to occur (Bilsborrow and Stupp, 1997).

The main merit of this *revisited theory of multiphasic responses* is to consider household decisions to allocate one or more of its members in some type of mobility, together with land management strategies (extensification and extensification) and fertility regulation. These are the four concurrent strategies to diversify risk and achieve desirable income and welfare levels. The Multiphasic responses approach also allows a clearer understanding of mechanisms through use land use and demographic processes are intertwined in household decision-making processes. However, Curran (2002) observes that the multiphasic model (in the origin al and revisited version) does not provide an adequate answer about the temporal dimensions of processes of land use and household compositional effects affecting responses such as population mobility. In this regard, the model can be further improved by incorporating both a temporal dimension (through household and land use life cycle elements) as well as the ability, in the livelihoods and capabilities framework, to predict compositional changes in the portfolio of capitals over time.


**Farm Household Composition and Lifecycles Mediating Household Livelihoods over Frontier Development Stages**

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[2]Besides the generic concept of "changes in living standards", Bilsborrow (1987) mentions a list of factors affecting the multiphasic responses: "the availability of untapped, potentially cultivable land; the availability of off-farm rural employment opportunities; the availability of urban employment opportunities; the potential for labor-intensive, land-saving technological change; the existing crop structure, and its capacity for change; the existing size of the rural population relative to the urban population; the prevailing level of rural fertility and the strength of factors maintaining its high level; the existing size of landholdings and their distribution; and the institutional structure."

Based upon the discussion on the theoretical perspectives in the preceding section, I suggest the distinction of three stages of frontier development in the Brazilian Amazon, considering how they are associated with farm household composition and lifecycles and the composition of capitals which defines livelihoods (Sherbinin et al. 2008, VanWey et al. 2012b). Frontier stages have a parallel with Marquette (2006) discussion about three phases of frontier development (*adaptatio*n, *experimentation,* and *consolidation*).

i) *Pioneer frontier*, corresponding to the first years of settlement by migrant colonists and characterized by high deforestation, incipient on-farm land use to meet family needs, high Youth Dependency Ratio and high engagement in off-farm (mostly rural) employment in a context of limited provision of infrastructure, public services and institutions;

ii) *Mature (or Expansion) frontier*, corresponding the next phase when farm households have opportunities to move gradually to a combination of more profitable land uses, such as perennials and cattle ranching, and take advantage of the smaller Dependency Ratio (children reaching young labor ages and entering the farm labor pool); and, finally,

iii) *Post-Frontier* (or *Consolidated frontier),*where farm households (usually with high Old Dependency Ratios) have more opportunities to diversify their livelihoods towards on and off-farm strategies in a context of urbanization, improved accessibility to urban labor markets, infrastructure, public services, and institutions.

The factors defining the evolution of frontiers over the three stages is conditioned on the articulation of micro-level dynamics (farm household lifecycles and livelihoods) to meso (community, regions) and macro-level factors related to the structure of opportunities and constrains given by the context (Barbieri, 2005; Barbieri et al., 2006; VanWey et al., 2012b; Barbieri and Pan, 2013; Barbieri et al., 2016). However, the growing influence of macro and meso level factors on household land use decisions takes place asymmetrically in different frontiers (Rodrigues et al. 2009), setting the stage for a unique dynamic for each frontier (Sawyer 1984; Browder and Godfrey 1997; Guedes et al. 2009). Although some frontiers may experience boom-and-bust cycles of development – from intense deforestation to land abandonment, thus not reaching a Post-frontier or even a Mature stage – there is a general trend of change in the economic environment of the frontier from subsistence to an increasing articulation with markets (Walker 2004). This implies that the influence of household life cycle factors on land use change and livelihood strategies decrease as frontier integrates into markets over time (Barbieri et al., 2005; Barbieri et al., 2006; Barbieri and Pan, 2013; Barbieri et al., 2016; Guedes et al. 2017b).

Population mobility is a key aspect of livelihoods strategies and as a response to the dynamics of household lifecycles over these different stages of frontier development. Barbieri (2006) mentions, for example, that out-migration and off-farm employment in the Northern Ecuadorian Amazon may be either complementary or alternative strategies, depending on household composition factors (especially the kinship relationship between members, the age structure, and the dependency ratios), and the characteristics of settlements by different cohorts. The same empirical regularities were observed in the Brazilian Amazon by VanWey et al. (2012a) and Guedes et al. (2017b).

Figure 1 presents the theoretical framework which unveils how demographic factors at the micro scale (households, individuals) is a key adaptation and mediation mechanism of farm household lifecycles and livelihoods composition over distinct stages of frontier development. In the Y axis we represent household demographic composition, particularly in terms of *age composition* (Dependency Ratios) as well as in terms of *labor allocation composition*, with distinct forms of mobility, including migration (internal or international) and off-farm employment (commuting, circulation, seasonal movements etc.). I depicture these two types of household composition along with their *temporal dimension* (X-axis), in terms of household lifecycle stage (with *age of the household head* as a marker) and their evolution in stages of frontier development, or *time in the frontier* (Pioneer, Mature, and Post-Frontier).
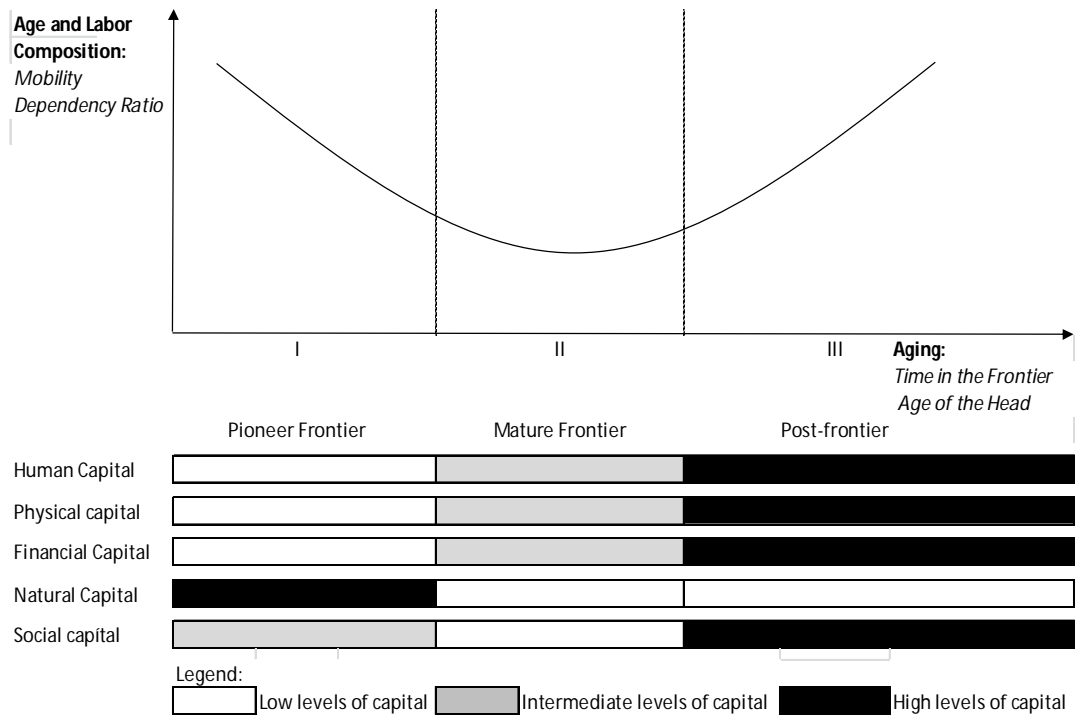
Figure 1 – Microdemographic factors mediating household lifecycles, livelihoods and frontier Development

The two most powerful markers of household lifecycles are defined in Figure 1 as *Dependency Ratio* (Y axis) and *Age of the Household Head.* The first is the ratio of consumers (e.g., population below 13 years of age and above 49 years of age) to consumers and producers (or the active population between 13 and 49 years of age). It derives from the classical Chayanovian measure of "Ratio of producers to Consumers" (Thorner et al., 1986). Distinct positions and combinations of this marker are expected to be related to distinct mobility levels. Dependency Ratio is usually higher i) in the initial stage of frontier development due to the younger household composition, usually a young couple (and lower age of household head) with small, dependent children (McCracken et al., 2002; Barbieri et al., 2006); in-migration to frontier is high (new settlements) as well as out-migration due to land turnover (VanWey et al. 2012a); the need of off-farm income due to the still incipient on-farm production is higher, thus increasing labor circulation (Sydenstricker, 1992); and ii) at the Post-Frontier stage, with older couples indicated by the higher age of household head, as well as smaller household size (McCracken et al., 2002; Barbieri et al., 2006) given out-migration of sons and daughters (Barbieri et al., 2011, Perz 2001). International out-migration (Caviglia-Harris et al., 2013; Barbieri et al., 2016) and off-farm employment fostered by urbanization and infrastructure development are also high at this stage (Barbieri et al., 2009a, 2009b; Pfaff et al., 2009; Barbieri and Ojima, 2018;).

While Dependency Ratio is higher in these two extreme stages of frontier development, its qualitative meaning is rather distinct: in the Pioneer stage, it is due to high *Youth Dependency Ratio*, while *Old Dependency Ratio* predominates in the Post-Frontier stage. Finally, Dependency Ratio is lower in the Mature stage due to the active labor force (head and spouse and most children at productive ages) and high labor demands for on-farm production favoring labor immobility (McCracken et al., 1999; Barbieri et al., 2006), especially in diversified land use systems characterized by the combination of more profitable land uses involving perennials, annuals, and cattle ranching (Barbieri et al., 2006; Guedes et al., 2017b; VanWey et al., 2009, 2012a).

Microdemographic factors such as Dependency Ratio, Population Mobility and Age of the Head mediate not only transitions over lifecycles, but also the ways farm households derive their livelihoods over stages of frontier development, as suggested in VanWey et al. (2012a). As shown in Figure 1, and following the previous discussion on Livelihoods and Capability approaches, I suggest that over stages of frontier development, farm households change their portfolio towards a combination of:

i) *accumulated capitals*, characterized by increasing educational, labor qualification and health standards (human capital), higher supply of machinery, tools, housing in urban areas and land consolidation (physical capital), access to off-farm labor wage, income from profitable land uses, credit, and cash transfer programs (financial capital);

ii) *depleted natural capital*, defined by decreasing income from wood due to past deforestation and extractive products at the plot, such as rubber trees and Brazilian nuts, albeit access to sources of water may increase due to its combination with increasing physical capital allowing collection, transportation and storage of water. These correspond to ex-ante stock of capitals with depletion rates that exceed the capacity of farm households to recover initial levels;

iii) *oscillating social capital*, moderately higher at the initial stages due to the strong migration networks favoring in-migration, informal, interpersonal and personal institutions such as cooperative work favoring off-farm labor opportunities and social services, as well as the presence of governmental institutions promoting land access (in the Brazilian case, the Institute of National Colonization and Agrarian Reform – INCRA). The farm household composition of social capital decreases at intermediate stages due to the consolidation of land distribution programs (albeit informal land markets arise) combined with the weakening of migration networks which favored the settlement of pioneer colonists, the rising (but still incipient) access to public services, and still incipient urban labor markets. At the Post-frontier, social capital is higher again due to the networks favoring off-farm mobility (especially towards urban areas), internal and international migration, higher accessibility to public services, and greater penetration of market institutions (urban labor, credit etc.).

I hypothesize that at each stage of frontier development and over the farm household lifecycle, microdemographic factors interacts with the five capitals (and their dynamics over time) to define a specific household portfolio composition. Notwithstanding, this composition and its dynamics over time are highly influenced by the access to mobility as a specific household livelihood response. In the *Pioneer Stage*, smaller levels of on-farm production due to the conditions of initial settlement (need to clear land for farm production, low levels of physical and human capitals, and imperfect credit and urban labor markets) increase farm household dependence on off-farm labor income, mostly related to agricultural labor in the form of waged and non-paid, collaborative work (Sydenstricker, 1992; Barbieri et al., 2016). Low levels of accumulated capitals foster a high portfolio composition towards social capital (especially those favoring off-farm employment, institutions favoring access to land markets, and networks of support of other family settler in-migrants), as well as intensive use of natural capital to derive income or used for consumption (e.g., building farm houses and infrastructure).

The *Mature Stage* delineates a profound change in the composition of capitals, with increasing portfolio of accumulated and more profitable capitals compared to the use of natural and social capitals in the Initial stage. Nonetheless, the low Dependency Ratio combined with the higher levels of accumulated capitals have positive effects on farm labor productivity (education, qualification, access to credits, increasing stocks of physical capital) and assures higher on-farm production based on more profitable land uses (perennials, commercial crops, and pasture for cattle ranching). At this stage, higher on-farm labor demand combined with

deprived levels of social capital (particularly migration networks and incipient urban labor markets) assures lower levels of mobility of farm household members.

The transition from the Mature to the *Post-Frontier Stage* begins with farmers developing livelihood strategies to take advantage of the new institutions emerging within the frontier, such as labor markets and markets for selling agricultural products (VanWey et al., 2012b). Access to financial capital, especially off-farm employment opportunities, together with cash transfer programs in Brazil (such as the non-contributory rural retirement and the *Bolsa Familia* program) also create off-farm cash opportunities and decrease small colonists' dependency on farm production and natural capital (Barbieri et al., 2009b; Guedes et al. 2012; Barbieri et al., 2016).

Old Dependency ratio and smaller household size in the *Post frontier* indicate high mobility of children due to life cycle transitions (e.g., the "empty nest effect" due to a son or daughter reaching adulthood and leaving to constitute his or her own household after marriage, or in search for education or labor opportunities in urban areas). Higher mobility facilitates the higher levels of accumulated capitals creating selectivity migration and off-farm employment profiles, due to age (young adult sons and daughters) and higher education for instance. Accumulation of physical capital also allows higher investments in land consolidation and pastureland and housing in urban areas, which contribute to reduce farm labor demands.

The accumulated capitals favors the adoption of mobility as a profitable household livelihood strategy, and in an endogenous fashion, higher mobility favors further accumulation of capitals in the Post-Frontier through remittances and off-farm income invested in human capital (education, health, qualification) and farm physical capital, as well as strengthening social (migration) networks and connection of rural and urban markets. However, while at later frontier stage and as a reaction to larger sociopolitical and economic transformations, small-scale producers are increasingly involved in off-farm activities and may become market-oriented (Murphy 2001; Perz 2005as in Caldas et al. 2007), they continue to derive livelihoods from subsistence agriculture. This is the basic difference between smallholders and large capitalist farmers in a Post-Frontier scenario (Ellis 1993; Browder & Godfrey 1997). Evidence from different agricultural frontiers in the Amazon supports this view. Although in some areas the share of agricultural production sold in the market reaches over 80%, an important part of this production is used for meeting immediate consumption needs of the household members (Marquette 1998; Walker et al. 2002; VanWey et al. 2007).

Post-frontiers may be also characterized by the exhaustion of natural resources and the out-migration of small farmers unable to cope with the fertility decline of the soil, farm labor shortage and experiencing limited access to subsidized credit (Pan and Carr 2016; Castro and Singer 2012). This mobile population fosters new streams of internal migration, providing cheap labor in other frontiers, or feeding migration and circulation streams to the growing urban centers of the region in search of urban employment (Barbieri et al. 2009a, Barbieri and Pan, 2013, VanWey et al. 2012b), or engaging in international migration (Barbieri et al., 2016).

Some forms of capital formation, such as participation in organizational membership, forms of *clientelism*, and different systems of reciprocity (Pieterse 2001) are important to smooth consumption and alleviate poverty (Guedes et al. 2012). However, these forms of social capital *per se* have limited effect in overcoming more structural causes of rural poverty, such as land concentration and lack of credit (Kay 2006). In this context, social networks (as a type of social capital) fostering migration or circulation of family members to urban areas and the formation of multi-sited rural-urban households have also been common strategies to generate income and bring about economic diversification (Barbieri *et al*. 2009b; VanWey and Vithayathil, 2013). Following de Haan (1999, p. 13), "keeping a foot on the farm, in which migration is part of a 'diversification' strategy is perhaps the most common motive". Kay (2018) discussion on the *New Rurality* framework applied to Latin America also shows the importance of part-time farming and non-rural activities – particularly those towards urban areas – as essential component of rural livelihoods. Still according to Kay (2018), rural population

may engage in multiple activities and have different degrees of insertion in the modern, urban markets as a way to adapt their livelihoods.

**Study Area: Machadinho, Brazilian Amazonia**

Machadinho is a municipality located in the state of Rondônia, in the Southwestern part of the Brazilian Amazon. A former federal Colonization Project, it has an area of 8,509 km$^2$ and population of 31,135 according to the 2010 Census. The Colonization Project was conceived in the Northwest Region Integrated Development Program (Polonoroeste), approved in 1981 and partly financed by the World Bank and the occupation of plots by farm colonists beginning in 1984 (see further discussion in Sydenstricker, 1992; Monte-Mór, 2004; Barbieri et al., 2009b). Figure 1 shows the spatial distribution of plots of the colonization project and the location of the study area in Brazil. By July 1985, Machadinho's urban nucleus became a booming little town, with over 1,500 houses, although about 30% of them were unfinished or only used as a second home—an "urban base"—for rural families (Sydnestricker, 1992; Monte-Mór, 2004). Those who live in the rural parcels may have succeeded due to comparative advantages in labor and/or technological resources. The ability to maximize opportunities and make a living from rural activities (staying in the assigned rural areas) was based on the capacity to guarantee both cash earnings and time and labor to work on the rural land (Monte-Mór, 2004; Barbieri et al., 2009b).
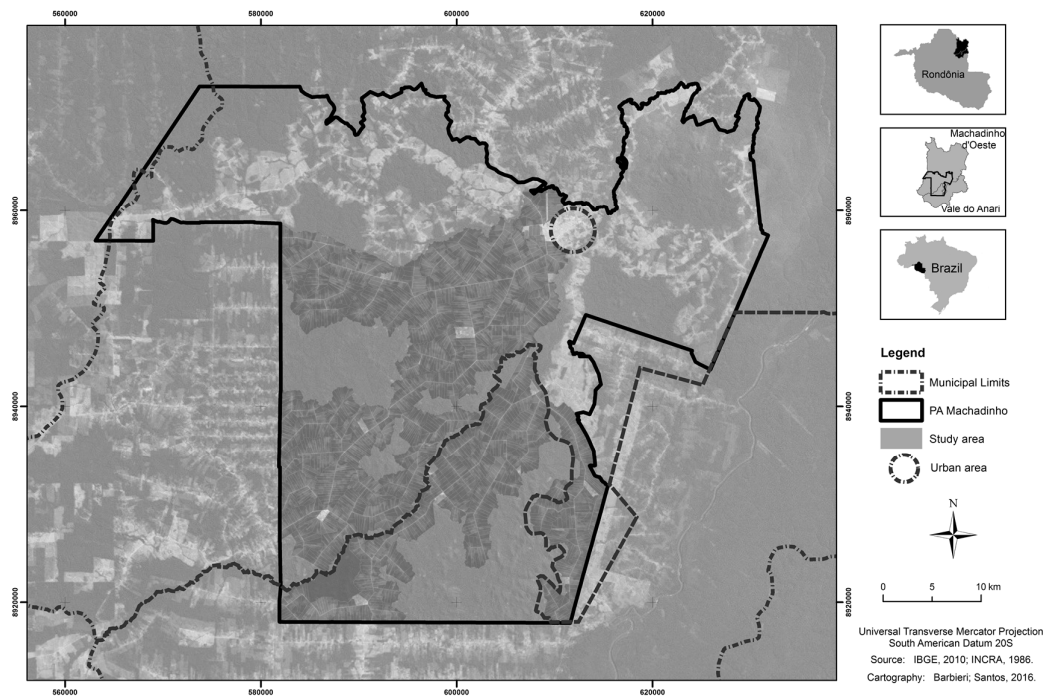


Figure 2 – Study Area in Machadinho D´Oeste, Brazilian Amazon

**Methods**

*Data and descriptive analysis.* We use twenty-five years of information collected in three field surveys in the municipality of Machadinho: 808 farm households and 3,961 individuals in 1987; 1,069 farm households and 5,031 individuals in 1995; and 259 farm households and 914 individuals in 2010. The first two correspond to the universe of all plots settled in the original colonization project in Machadinho. Regarding stages of frontier

development (Figure 1), the 1987 data typically represents a *pioneer frontier*, while the 1995 data represents a *mature frontier*. The 2010 survey (representing a *post-frontier*) corresponds to a two-stage sample of farm households. While this last sample is smaller than the previous samples, it depictures a later stage in frontier development with land consolidation and land turnover determining a smaller number of farm households compared to the previous years.

These three *cross-sectional samples* allow us a descriptive analysis of key factors representing farm household dynamics and livelihood strategies at each stage of frontier development. Regarding household dynamics, we organize the descriptive data in terms of the key dimensions of household lifecycles and demographic composition suggested in Figure 1 – mobility, dependency ratio, age of the head and spouse and time of settlement (frontier stage). Data on livelihoods is organized in terms of the composition of household portfolio of capitals (Human, Physical, Financial, Natural, Social).

While the cross-sectional samples mix cohorts with distinct arrival and settlement times in each of the three stages of frontier development, I also identified and analyzed *a panel sample* following over time 77 farm households and their plots interviewed in 1987, 1995, and 2010. These may include households composed both of the same nuclear household (i.e., original head of household or spouse, or his son or daughter), or plots that changed household ownership during this time. The first group represents 45% of the 78 farm households. This panel allows us to understand how *settlement cohort effects* – controlling the time of settlement and exposure – affects the evolution of livelihoods for the same plots and farm households.

Land use data (organized as component of household financial or natural capital) were classified into annuals, perennials, pasture, primary forest, secondary forest, and bare soils for 1987, 1995 and 2010 using *based-object* classification (Barbieri et al., 2016). We use images provided by the sensor TM (Thematic Mapper) of the Landsat 5 for the three dates closest to the surveys dates: July 1987, August 1995, and June 2010 (Barbieri et al., 2016). For the purpose of analytical land use and cover classes, we combine bare soils and pasture into a sole class.

*Multivariate analysis.* I use two steps to test the relationship between household demographics and lifecycles and livelihoods depictured in Figure 1. The first step is to establish a typology of farm household composition and lifecycles using Principal Component Analysis (PCA), using the variables *Dependency Ratio, Proportion of Household Members in Off-farm Employment, Time in the Frontier (Machadinho), Age of the Household Head, and Household Size*. This last was used due to its being both a marker of frontier aging - a consequence of the advancement of demographic transition and decreasing fertility – and consequence of changing household composition due to an *empty nest* effect, when children reach adulthood and leave parent´s house for labor or marriage reasons. These two effects combined lead to smaller households over time.

In order to assure the assumptions underlying PCA (Hatcher, 1994), these variables were standardized in the interval-level measurement and have a normal distribution. I used the principal axis method to extract the components followed by a varimax (orthogonal) rotation, and the eigenvalue-one criterion (Kaiser criterion) to retain and interpret components with an eingenvalue greater than one (Hatcher, 1994). Variables presents large loading (0.40 or above) in a given component was retained for analysis, and in the case of a variable loading on more than one component, it was dropped from the analysis (Hatcher, 1994).

The second step is to use the factor scores generated through PCA in the cross-sectional and panel samples as well as the variable *time (years) in Machadinho* as predictor (dependent) variables for each year in the cross-sectional and panel samples (Equation 1):

$$y = \beta 0 + \beta 1\, x1 + \cdots + \beta m\, xm + \epsilon \quad + \qquad (1)$$

where $y$ is the response or dependent variable, $\beta 0, \beta 1, \ldots, \beta m$ are unknown parameters, $x1, x2, \ldots, xm$ are the regressor, or independent, variables, and $\epsilon$ is a random error term.

**Results**

*Descriptive analysis: demographic dynamics, land use and livelihoods.* Figure 3 and Graphic 1 shows the evolution of land uses in the study area between 1987 and 2010. Increasing deforestation and conversion to other land uses in the 1970s to the 1990s by small farm settlers follows tradition patterns in the Brazilian Amazon, with deforestation initially for mostly annuals (7.4% of cultivated land) and perennials (9.2%) in the mature frontier. Land in pasture is residual (0.6%), albeit the proportion of bare soil (5.1%) may indicate a stage of transition from clear land to the formation of pastureland. At this stage, primary forest still represents a large proportion of land cover (74.1%). At the post-frontier, there is higher balance in land uses, but with a relatively higher proportion of pasture (39.1%) vis-à-vis annuals and perennials (28.7%). Primary forest decreases by about half (35.4%).

Table 3 shows the dimensions and variables used to evaluate farm household life cycle and livelihood strategies at each stage of frontier development. The percentages of land uses refer to a sample (see description in the Session "Methods") for the entire plots shown in Figure 3. We classify Annuals and Perennials as components of financial capital (both cash crops and subsistence price-equivalent crops), while primary forest is a component of natural capital. Table 3 shows that deforestation trends in the sample follow the one depictured in Figure 3 and Graphic 1. The percentage of land in annuals and perennials is smaller in the sample (5.5% compared to 16.6%), albeit pastureland is significantly higher in the sample (41% compared to 0.6%). This indicates that farm households in the sample faces a more advanced transition of land uses, as predicted by household and plot life cycle theories, compared to the whole settlement area in Machadinho. Pastureland continues as the most important share of plot land use in the frontier, but annuals and perennials assume a more significant role (26.0%, close to the whole settlement area in Machadinho). This higher intensity of plot land use occurs at the expense of higher deforestation.
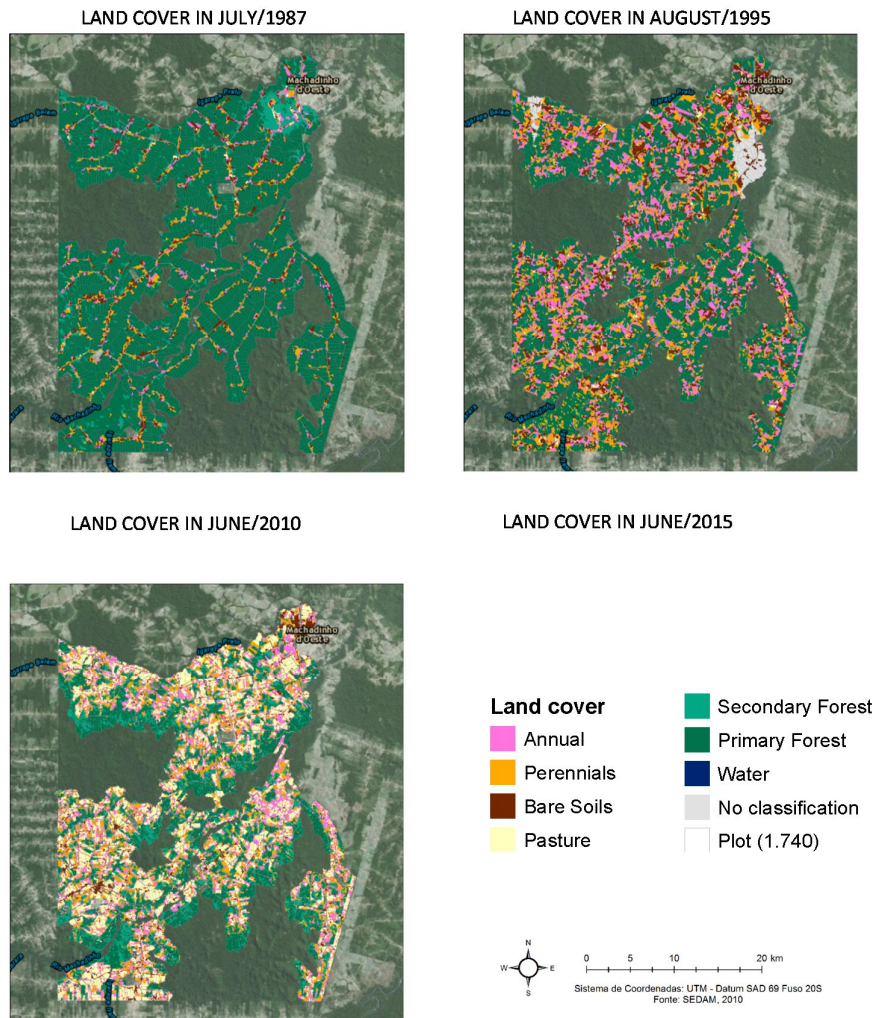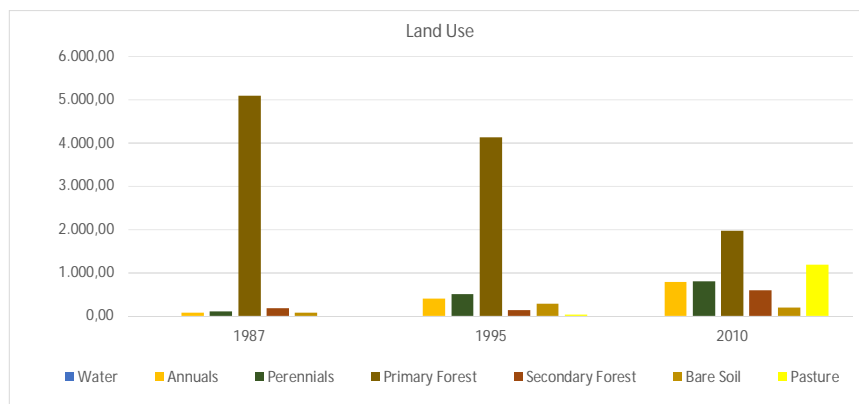
Figure 3 – Land Use Classification in Machadinho D´Oeste, Brazilian Amazon according to frontier stages – Pioneer (1987), Mature (1995) and Post-frontier (2010)



Graphic 1 – Evolution of Land Uses in Machadinho D´Oeste, Brazilian Amazon according to frontier stages – Pioneer (1987), Mature (1995) and Post-frontier (2010)

Regarding *markers of household life cycle*, Table 3 shows that farm households at later stages in the frontier (2010) have an older age structure, as indicated by the mean age of household head and spouse, and by the older household dependency ratio. While Dependency

Ratio is also high in the Pioneer frontier, it is of a different composition (a younger dependency ratio), while the intermediate level in the Mature frontier implies a higher proportion of labor active population ate the farm households.

Furthermore, and following the conceptual framework depictured in Figure 1, figures 2 and 3 show dispersion analysis between pairs of markers of household lifecycles and composition. While the fit is usually low for each pair of markers (except for Dependency Ratio and Age of the Head in Graphic 3), the visual inspection suggests an adherence to the expected pattern defined in Figure 1 according to specific stages of frontier development .

Mirroring the advanced process of demographic transition in Brazil, household size declined when compared to earlier years, and other variables show changes in farm household as well: Household Sex Ratio is slightly smaller in 2010 (1.2) compared to previous years (1.3 in 1987 and 1995). Older household age structure compared with the higher farm activity and income levels due to the accumulation of capitals may explain the reliance on a higher share of hired (external) farm labor in 2010 compared to 1987. While we do not have comparative data for 1987 and 1995, the high proportion of households adopting both out-migration and international emigration shows that population mobility is an important component of livelihood strategies in Machadinho. The United States are the main destination for these migrants (32%), followed by the rural frontier in Paraguay (30%) and Portugal and Spain (24%) (figures not shown).

The overall level of *human capital* is usually low in terms of education for both head and spouse, albeit we can expect that education of younger household members may increase due to the advancement of public education over the last decades. This may also explain higher off-farm (especially urban) labor opportunities for household members over time (a proxy variable for labor qualification for labor markets external to the farm).

There is an increase over time in two components of *physical capital:* ownership of cattle and land consolidation (ownership of other rural plot). Both are intimately related, since rising cattle ranching requires larger extensions of land. Nonetheless, farm households at later stages in the frontier adopt more profitable land use strategies based on cattle ranching. This seems to be related to their smaller family size in accordance to the stage in their household life cycle, and because annuals and perennials are more labor demanding. The high proportion of households owning the land (particularly in the pioneer and post-frontier) reflects a stable land tenure context, while ownership of land or plot in the city remains relatively stable over time (between 13% and 16.5%).

Regarding components of *financial capital*, while on-farm activities remain the main source of income in the mature and post-frontier, they also adopt more efficient income diversification strategies, with higher number of family members in off-farm activities and with remittances from out-migration (while this last is only measured in 2010). As a matter of fact, while in 1987 the small proportion of income from on farm activities reflects the initial stage of settlement, on farm production increases over time and reaches a peak 2010 (82.5%), while off farm income diversification remains a relatively smaller component of farm household production. In association with the larger penetration of the Brazilian welfare state, older households in 2010 have a sourced a high share of their incomes from governmental cash transfer programs, and show specialization in less-demanding labor activities. Farm households have more than doubled their access to credits of loans from 1995 to 2010 (18.2% to 46.9%); combined with the increasing proportion of hired labor over time, this result suggest the advancement of markets (financial, labor) mi the post-frontier with the consequent changes in the way households make their livings.
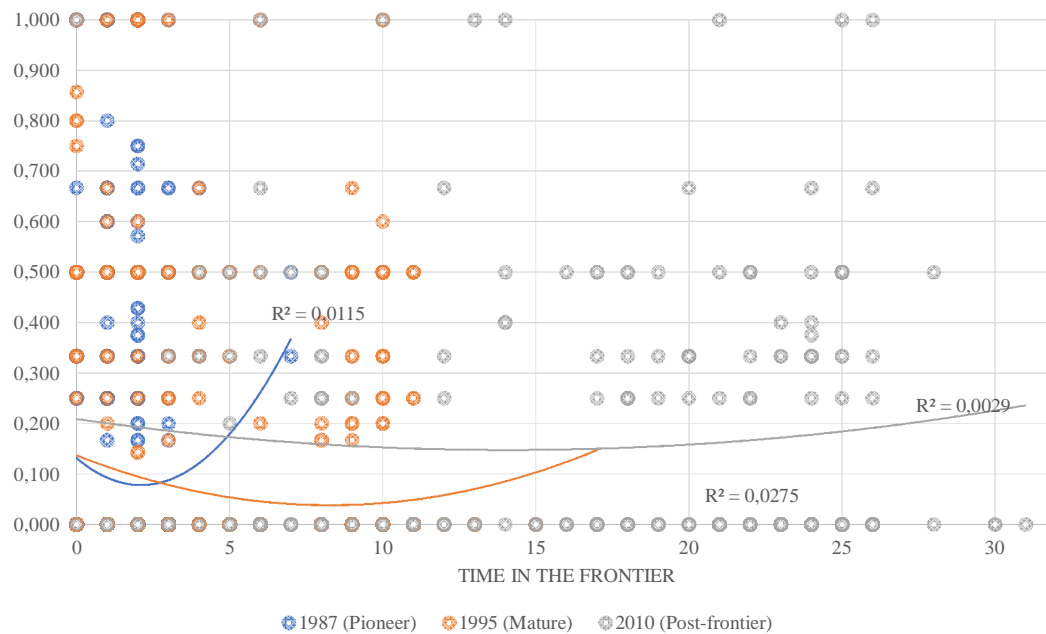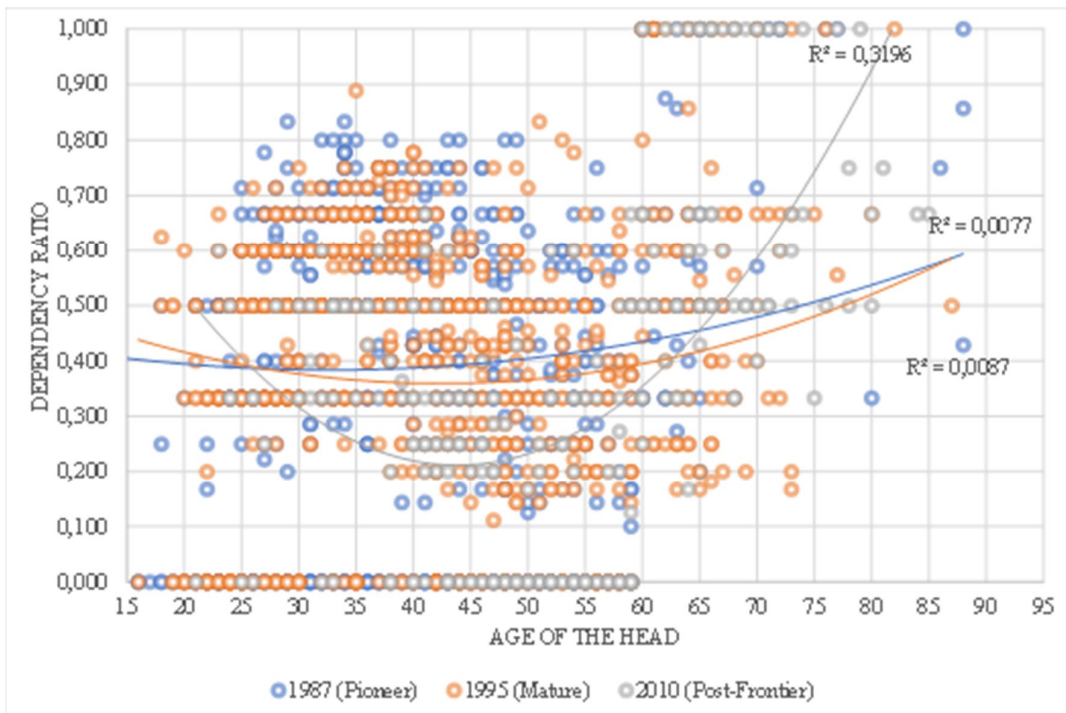
Graphic 2– Relationship between markers of household lifecycle and composition in the cross-sectional sample and across stages of frontier development - Pioneer (1987), Mature (1995) and Post-frontier (2010)
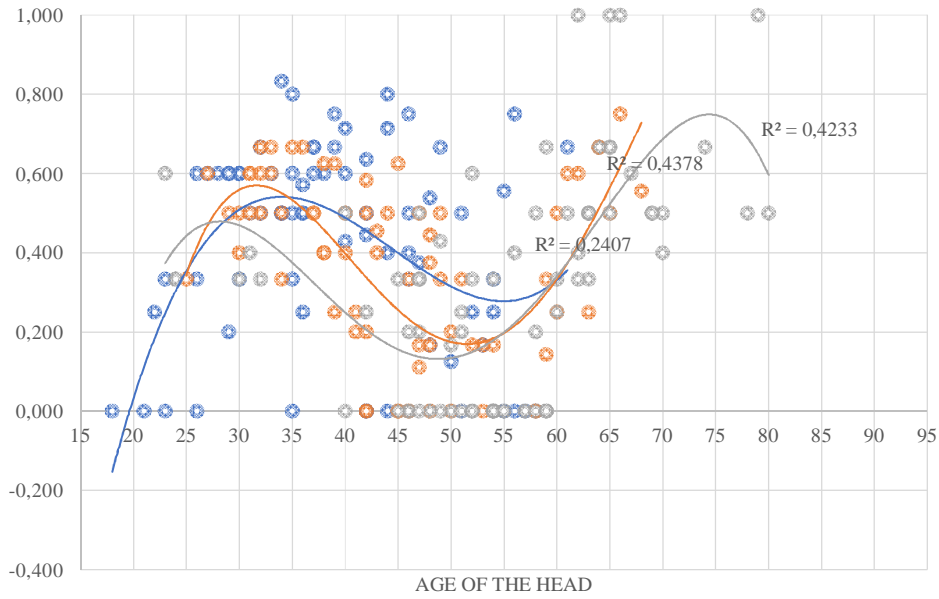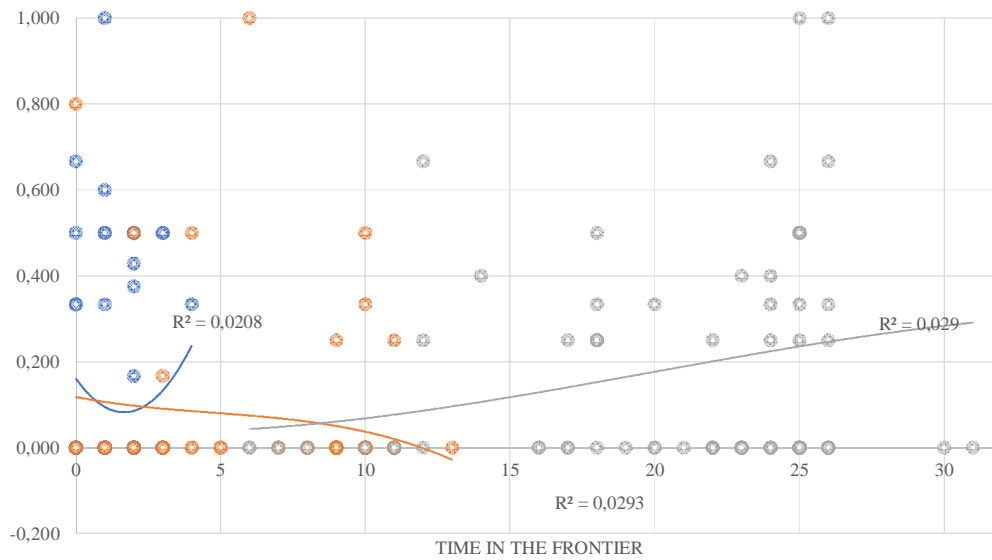
Graphic 3– Relationship between markers of household lifecycle and composition in the panel sample and across stages of frontier development - Pioneer (1987), Mature (1995) and Post-frontier (2010)

Diversification of household portfolio in terms of financial capital from remittances, off-farm income, and government cash transfer may be facilitated by multigenerational cohabitation patterns, particularly vertically extended families (multiple families in cohabitation) which may create family support to release particularly young labor to off-farm activities, and assure income flows for older parents (through pensions) or for the younger ones (from governmental programs such as *Bolsa Familia*). This is a key component of farm household *social capital* which has increased over time in parallel to the reduction in the proportion of nuclear families. As suggested by Sydenstricker (1992), most pioneer settlers in Machadinho had birth or last migration stage in Southern or Southeastern Brazil, and as the frontier ages and the second generation of colonists becomes relatively larger, the proportion of natives from the Northern region increases (mostly natives from Rondonia), the inter-regional accumulated migration decreases and the proportion of new migrants into the frontier decreases. The proportion of individuals born in the Southeast remains relatively stable over time and increases its representation as the last region of residence.

Finally, higher reliance on more profitable capital strategies - off-farm employment, out-migration, and cash transfer programs – may decrease reliance on *natural capital* as a source of farm household income, as indicated by the decreasing share of land on forest and extractive activities.

Overall, and as suggested in Figure 1, over time farm households increasingly accumulate physical and financial capital and some human capital (especially those allowing access to off-farm employment opportunities), taking advantage both of the time of settlement with accumulation of resources to invest both in on-farm production as well as the housheold demographic composition which favors off-farm opportunities, such as income from off-farm (urban or rural) labor or migration. This accumulation of capitals occurs at the expense of the depletion of natural capital, particularly primary forest and extraction (rubber trees, Brazilian nuts etc). Farms households may also take advantage of the opportunities given by the peculiarities and oscillations of social capital at different stages, e.g., access to settlement institutions and social bonding at earlier frontier stages (Sydenstricker, 1992), or family arrangements in the pros-frontier which favor the allocation of farm labor in profitable off-farm opportunities.

Compared to the cross-sectional samples, the panel sample follows the same pattern but with differences in levels of some specific variables: households have usually have older heads, more members who out-migrated, smaller education of heads in the pioneer and mature frontiers and smaller education of spouses since 1995. There are significant differences in physical capital only for 1995 (higher percentage of households with cattle and ownership of other plots in the panel); differences in income from on-farm production in 1987 and 1995 (financial capital); and a higher share on multigenerational households in 2010 (social capital).

Table 1 - Descriptive statistics: sample, markers of household life cycle, household composition of capitals in Machadinho D´Oeste – 1987, 1995 and 2010

| Dimension of analysis | Variable | Frontier Stage (Cross-sectional) | | | Frontier Stage (Panel) | | |
|---|---|---|---|---|---|---|---|
| | | Pioneer 1987 | Mature 1995 | Post-frontier 2010 | Pioneer 1987 | Mature 1995 | Post-frontier 2010 |
| Sample characteristics | Number of farm households | 808 | 1069 | 259 | 77 | 77 | 77 |
| | Number of individuals in the plot | 3961 | 5031 | 914 | 429 | 410 | 270 |
| Farm households: composition and markers of life cycle | Dependency ratio [a] | 0.40 | 0.38 | 0.35 | 0.42 | 0.38 | 0.32 |
| | mean age of head of household (years) | 40.0 | 42.3 | 52.2 | 39.3 | 45.0 | 54.5 |
| | Time in Machadinho (years) | 1.6 | 5.8 | 17.7 | 1.4 | 7.2 | 20.9 |
| | Mean household size | 4.9 | 4.7 | 3.5 | 5.6 | 5.3 | 3.5 |
| | farm households hiring laborers (%) | 31.4 | - | 44.0 | 30.7 | - | 46.8 |
| | sex ratio | 1.3 | 1.3 | 1.2 | 1.3 | 1.2 | 1.2 |
| | households with out-migrants in the last 5 years (%) | - | - | 60.0 | - | - | 75.3 |
| | households with at least one international out-migrant (%)[b] | - | - | 13.4 | - | - | 13.0 |
| Human Capital | heads with more than 4 years of education (%) | 7.0 | 11.3 | 8.3 | 1.3 | 7.8 | 9.5 |
| | spouses with more than 4 years of education (%) | 4.5 | 17.6 | 14.9 | 7.8 | 13.0 | 9.4 |
| | % individuals over 14 y.o. in off-farm employment | 9.3 | 6.7 | 16.8 | 11.1 | 6.0 | 18.8 |
| Physical Capital | farm households owning cattle (%) | 13.6 | 62.6 | 85.3 | 15.6 | 76.7 | 81.8 |
| | head own the plot in Machadinho (%) | 88.1 | 76.0 | 89.2 | 90.9 | 93.2 | 89.6 |
| | own other rural plots (%) | 8.4 | 20.3 | 32.7 | 2.6 | 33.8 | 29.9 |
| | ownership of land / house in the city (%) | 16.3 | 13.1 | 16.2 | 17.1 | 10.8 | 16.9 |
| Financial Capital | % income from on farm production[c] | 32.7 | 73.8 | 82.5 | 11.6 | 84.1 | 82.6 |
| | households receiving government cash transfers (%) | - | - | 44.4 | - | - | 53.4 |
| | households with credit or loans (%) | - | 18.2 | 46.9 | - | 30.1 | 50.6 |
| | land in pasture (%) | 9.9 | 41.0 | 39.1 | 10.5 | 43.6 | 40.9 |
| | land in annuals and perennials (%) | 4.4 | 5.5 | 26.0 | 4.1 | 5.1 | 23.7 |
| Natural capital | land in primary forest (%) | 80.1 | 49.2 | 28.1 | 80.1 | 46.8 | 29.0 |
| | households with extractive production (%)[d] | 1.2 | 18.4 | 9.6 | 1.8 | 25.0 | 10.4 |
| Social capital | heads born in South/Southwest Brazil (%) | 71.3 | 73.7 | 72.0 | 72.0 | 72.0 | 72.0 |
| | nuclear family - parents and sons only (%) | 83.9 | 88.0 | 76.9 | 81.8 | 90.5 | 68.8 |
| | multigenerational household (%)[e] | 2.8 | 2.0 | 15.4 | 3.9 | 0 | 26.0 |

Source: Machadinho Dataset (1987, 1995, 2010)

[a] Sum of the population until 12 years old and the population 50 years old or more, in the numerator, divided by the population between 13 and 49 years old in the denominator

[b] Living at the household or abroad at the date of survey. Total of 50 international out-migrants identified, in 35 households.

[c] Includes income from agriculture (annuals and perennials) and animals (pigs, chickens, horses etc) rather than cattle).

[d] It refers, before 2010, to the existence of seringas (rubber tree); in 2010, to seringas, apiculture and fish ponds.

[e] Farm households cohabited by at least grandsons and grandparents.

*Multivariate analysis:* For each of the six PCA ran in 1987, 1995 and 2010 in the cross-sectional and panel samples, only the first two components showed eigenvalues greater than 1 and were thus retained for rotation. Tables 2 and 3 show the estimates for rotated factors, final communalities and the variance accounted for each pair of components. The rotated factors in bold are those with large loadings in each component (0.40 or above) which defined the qualitative meaning for each of the two selected components in each column for a given year and sample.

The components for 1987 and 1995 have similar meanings in the cross-sectional samples. The first indicates the importance of age composition (household dependency ratios) and household size in pioneer and mature frontiers, where livelihoods are highly dependent on on-farm activities, while the second indicates that off-farm labor diversification are highly associated with time exposure (of households and his/her head) in the frontier environment. In contrast, age composition rather than household size becomes more associated with time exposure (households and heads) in the post-frontier (2010) in the first component, while household size becomes more associated with labor composition.

Regarding the panel samples, the difference in the first components for 1987 compared to the cross-sectional sample is that in the later, time in Machadinho did not presented significant association with the other two variables (household size and age composition). Overall, the results for the first component in the panel samples in the pioneer and mature frontier follows the qualitative meaning presented in the cross-sectional samples. Regarding the second component, only age composition was significant to define household composition and lifecycle markers in the pioneer frontier, while labor composition was highly associated with time exposure of households in the frontier at the mature frontier. Age of the household head was dropped from the analysis in 1995 since it had loadings over 0.40 for both components. Finally, the second component in the post-frontier had the same qualitative meaning of the post-frontier in 2010.

The rotated factors, with their names and qualitative meanings as discussed above, and the variable *time (years) in Machadinho* were used as predictor (dependent) variables for each year in the cross-sectional and panel samples. I use variables representing human, physical, financial, natural and social capital

***Dear reviewer: we are currently preparing the results of the multiple linear regressions. Final results will be ready by late November or early December at most. I will use my previous expertise in the construction of several types or multivariate models (see, e.g., Barbieri et al., 2005; Barbieri, 2006; Barbieri et al., 2009 a; Barbieri and Pan, 2013).***

Table 2 - Rotated Factor Pattern and Final Communality ($h^2$) Estimates from Principal Components Analysis of Farm Household Composition and Lifecycle in the Cross-sectional samples

| Variable | Pioneer 1987 | | | Mature 1995 | | | Post-frontier 2010 | | |
|---|---|---|---|---|---|---|---|---|---|
| | size and age composition | aging/labor composition over time | $h^2$ | size and age composition | aging/labor composition over time | $h^2$ | Age/aging composition over time | size and labor composition | $h^2$ |
| Dependency ratio | **0.86** | -0.03 | 0.75 | **0.83** | -0.05 | 0.70 | **0.70** | 0.20 | 0.52 |
| mean age of head of household | 0.21 | **0.63** | 0.44 ] | 0.13 | **0.63** | 0.42 | **0.83** | 0.03 | 0.69 |
| Time in Machadinho (years) | -0.14 | **0.71** | 0.52 | -0.15 | **0.69** | 0.50 | **0.50** | 0.03 | 0.25 |
| Mean household size | **0.86** | 0.08 | 0.75 | **0.83** | 0.09 | 0.70 | -0.38 | **0.64** | 0.56 |
| % over 14 y.o. in off-farm employment | -0.01 | **-0.43** | 0.18 | -0.05 | **-0.62** | 0.39 | 0.08 | **0.79** | 0.64 |
| Accounted variance | | | 0.53 | | | 0.54 | | | 0.53 |

Table 3 - Rotated Factor Pattern and Final Communality ($h^2$) Estimates from Principal Components Analysis of Farm Household Composition and Lifecycle in the Panel sample

| Variable | Pioneer 1987 | | | Mature 1995 | | | Post-frontier 2010 | | |
|---|---|---|---|---|---|---|---|---|---|
| | size and age composition over time | age composition | $h^2$ | size and age composition | labor composition over time | $h^2$ | Age/aging composition over time | size and labor composition | $h^2$ |
| Dependency ratio | **0.81** | 0.19 | 0.70 | **0.80** | -0.01 | 0.64 | **0.69** | 0.10 | 0.49 |
| mean age of head of household | -0.26 | **0.84** | 0.77 | - | - | - | **0.79** | -0.27 | 0.70 |
| Time in Machadinho (years) | **-0.55** | 0.27 | 0.38 | 0.04 | **0.77** | 0.59 | **0.45** | 0.32 | 0.30 |
| Mean household size | **0.54** | 0.72 | 0.81 | **0.80** | 0 | 0.65 | -0.27 | **0.74** | 0.62 |
| % over 14 y.o. in off-farm employment | 0.28 | -0.02 | 0.08 | 0.05 | **-0.76** | 0.58 | 0.32 | **0.67** | 0.56 |
| Accounted variance | | | 0.55 | | | | | 0.61 | 0.53 |

## Conclusions

   In this paper we explored how microdemographics – household composition and lifecycles - is a key mediation mechanism mediating household livelihood strategies over different stages of frontier developments We found empirical evidences, based on the study case on Machadinho D´Oeste in Rondonia, that supports the theoretical framework depictured in Figure 1.

*Dear reviewer: we will prepare the conclusions after finishing the interpretation of the results from multiple linear regressions.*

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