# Migration, Livelihoods and Development in the Post-frontier: Evidences from the Brazilian Amazonia

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**Abstract.** We use a twenty-five years panel of plots and households in Machadinho, Southern Brazilian Amazon, to show how population mobility over time is explained by the changing demographic composition, access and diversification of livelihoods as well as different stages of frontier development. The methods combine descriptive statistical analysis and the identification of profiles of livelihoods, household lifecycles and population mobility using latent class models. We show that highest levels of income and welfare are associated with households which diversify their livelihoods particularly in terms of mobility strategies. Despite anecdotal stories on the survival of stronger in the frontier, these may survive with deprived levels of capitals since more profitable migration strategies are income-selective. On the other hand, younger households in the frontier are a selective group, with more complex mechanisms for income generation, since they are entering a more urbanized and market-oriented frontier requesting higher levels of human capital.

**Keywords.** Population mobility, household and plot lifecycles, livelihoods, development, Brazilian Amazonia.

## Introduction

This paper discusses how population mobility in the Amazonia over time may be explained by the changing demographic composition, their access and diversification of sources of income, welfare and livelihoods, as well as development stages of frontier settlements. From a demographic perspective, it highlights the importance of household dynamics (including factors such as household size, composition, aging, intergerational and government transfers) and livelihoods strategies on population mobility. From a broader perspective, we analyze how these factors assume different meanings at each stage of frontier development when a diversity of factors such as globalization, expansion of international market-oriented activities, infrastructure building and migration networks play a diversity of roles to affect internal and international migration and labor mobility in the Brazilian Amazon.

We review the extant literature on the nexus between livelihoods, household and land use life cycles, and mobility in the Amazon basin at different stages of frontier development and suggest the need to better frame and understand how these factors respond to distinct stages of frontier development (see De Haan, 1999, Barbieri et al., 2005; Barbieri, 2006; Barbieri et al. 2009a; VanWey et al., 2012; Barbieri and Pan, 2013). In our view this gap in the

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literature results from the difficulty of well-established livelihoods approaches and farm household life cycle theories to adequately understand the multiple dimensions and meanings of population mobility in frontier areas. These theories are particularly useful to understand the 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. However, they do not adequately discuss how these factors may simultaneously connect household strategies to distinct forms of mobility decisions such as internal or international out-migration, or off-farm employment decisions linked to seasonal movements or commuting. Furthermore, distinct mobility decisions are usually mutually conditional and dependent from each other and are endogenous to livelihood strategies at specific household lifecycles and stages of frontier development (Barbieri, 2006).

We investigate the linkages between population mobility, household life cycles, livelihoods and stages of frontier development for the municipality of Machadinho, in the Southern Brazilian Amazon, using descriptive statistics, spatial analysis and latent class models. There are two reasons to choose Machadinho. First, it is within the most dynamic area of occupation by migrant colonists and the contemporary space of expansion of capitalism 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 thirty years (from 1985 to 2015); to the extent of our knowledge, this is the only study area in the Amazon with survey data for the same plots and households since the very onset of occupation and for so long, thus representing distinct stages of frontier settlement.

**Demographic dynamics, livelihoods and development in the Amazonian frontier**

As in many other conceptual frameworks, agriculture frontiers evolve in phases towards progressive market integration (Caldas et al. 2007). However, the growing influence of macro and meso level factors on land use decisions at the household level 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). 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.

Regardless of land speculation which continues to be an important component of environmental change (and particularly deforestation) in the Amazon, the expansion of soy bean, sugar cane and cattle ranching for national and international markets and infrastructure developments have redefined livelihoods in the region. While these activities have socioeconomic, demographic, and environmental impacts per se, they increase land costs and create economies of scale for large agriculture and cattle ranching activities, which become increasingly more competitive vis-à-vis traditional, small-scale colonization.

These transformations in the contemporary or post-frontier also create a new momentum on population mobility and urbanization in the Amazon. Off-farm employment opportunities, together with relative new cash transfer programs in Brazil (such as rural retirement and the *Bolsa Familia* program) also creates off-farm cash opportunities and decreases small colonists' dependency on farm production and natural capital. Nonetheless, the unfolding demographic transition in the Amazon, with decreasing fertility, population

aging, and relatively smaller population in the active working ages may challenge the sustainability of family labor activities in the next decades.

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. This mobile population fosters new streams of internal migration, providing cheap labor in other frontiers, or feeding migration and circulation streams to the urban centers of the region in search of urban employment (Barbieri et al. 2009a, Barbieri and Pan, 2013). This last aspect reveals that the way the relation between the rural and the urban develops is key to understand how local farmers interact with the environment beyond the frontier boundaries (Monte-Mór 2004).

Farmers, therefore, develop new livelihood strategies taking advantage of the new institutions entering to and emerging within the frontier space, such as labor markets and markets for selling agricultural products (VanWey et al., 2013). Population mobility reflects the dynamic nature of livelihood strategies, with the shifting portfolio of capitals as perceived returns to capitals changes through frontier development, creating incentives for diversification over space and across economic sectors (Guedes et al. 2014, VanWey et al. 2013). In this regard, population mobility and redistribution may become increasingly the dominant demographic factor in frontier regions over the next decades, considering that fertility and mortality levels tend to be reduced. The second and third generation of settlers will continue to reach adulthood and seeks more land or jobs, combined with the declining capacity of farms to sustain members due to population growth and decreasing soil quality with use over time, and therefore declining agricultural yields.

Rural-rural migration and off-farm employment may continue to be common types of mobility, representing a potentially powerful proximate determinant of deforestation and future threat to loss of biodiversity in the Amazon. Furthermore, the expansion of the agricultural frontier (with intra-frontier migration) threatens areas of permanent conservation (national parks) and forest areas rich in cultural biodiversity, as well as species biodiversity (Mena et al., 2006; Barbieri et al., 2009a).

Rural-urban mobility and international emigration , at later stages of frontier development may become increasingly important. Given the selective nature of migration, with the more educated and younger individuals moving more, rural production may be affected by the loss of educated manpower (Bilsborrow *et al.*, 1984). The other side of the coin is that the Amazon is facing rapid urbanization, with recent rapid growth of some long settled river towns, the formation of new pioneer urban areas, and the incipient transformation of many rural communities into towns, which are acquiring urban characteristics through population growth and acquisition of basic infrastructure (Barbieri et al., 2009b). Even improvements in rural livelihoods or the adoption of more supportive agricultural policies are not likely to much affect urbanization, as illustrated by historical examples in Latin America and other parts of the world (Martine and Guzmám, 2002).It is also likely that individuals will generally be better off by moving away from farms. Population mobility in both forms of out-migration and off-farm employment may improve income and welfare, and migration to urban areas or international emigration may also reduce overall fertility (with migrants to urban areas reducing fertility) and improve the efficiency of the economy (Barbieri, 2006).

Thus, it is important to depict population mobility as a key aspect of livelihoods strategies and as a response to both dynamics of household lifecycles over 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, age structure, and dependency ratios), and characteristics of cohort settlement.

Population mobility at different stages of frontier development may be at least partially explained by the way livelihood strategies respond to changes in the household composition and in the structure of constrains and opportunities given by the context, as suggested by household and plot life cycle (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. 2013). These theories focus on the household level and are particularly useful to understand the many components of colonist´s decision-making regarding livelihoods, 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.

A household livelihood can be seen as a portfolio of some combination of distinct assets which are accumulated over time and are shaped and can change their composition due to contextual factors such as social, cultural, political, and economic opportunities and constraints. Poverty in rural populations is defined as the general lack of choices and opportunities that are reflected in low levels of capital. These levels define rural dimensions of wellbeing on the conceptual rural livelihood framework as 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."*

A key element in livelihood approaches is the household ability to respond to periods of scarcity through a diversity of mechanisms, such as participation in organizational membership, forms of *clientelism*, and different systems of reciprocity (Pieterse 2001). 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). As a reaction to larger sociopolitical and economic transformations, small-scale producers are increasingly involved in off-farm activities (Murphy 2001; Perz 2005).

In this context, 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). 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 (2008), 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.

As the frontier evolves over time, the individual and household characteristics and motivations may shape new livelihood strategies given the contextual opportunities and constrains. Nonetheless, although at a later frontier stage farmers may become market-oriented (as in Caldas et al. 2007), they continue to derive some livelihood from subsistence

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).

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 household structure, as predicted by household life cycle theories (Ellis 1988, 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 livelihood approaches, 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) as well as livelihoods approaches.

**Study Area: Machadinho, State of Rondonia, Brazil**

Machadinho is a municipality located in the state of Rondônia, in the southern 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 Monte-Mór, 2004). 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 (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).

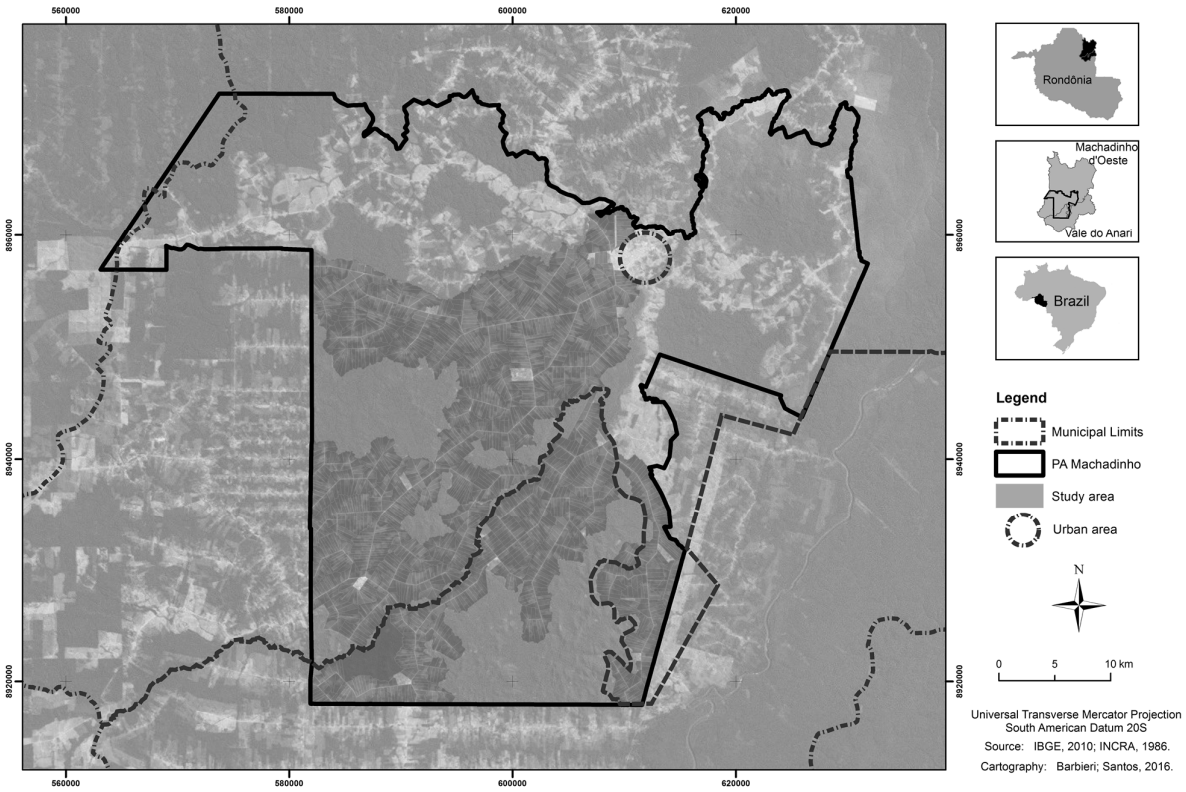


Figure 1 – Study Area in Machadinho D´Oeste, Brazilian Amazon

## Methods

*Data*. The analysis is based upon twenty-five years of information collected in five field surveys in the municipality of Machadinho. There are 284 farm households and 1,697 individuals in the 1985 survey; 568 farm households and 2,762 individuals in 1986; 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 1985, 1986, 1987, and 1995 surveys correspond to the universe of all plots settled in the original colonization project in Machadinho. The 2010 survey 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 initial occupation.

*Descriptive analysis.* The analysis begins with a descriptive analysis of key factors representing farm household life cycles and livelihood strategies (including population mobility) at each stage of frontier development The information to compare longitudinally (from 1985 to 2010) are a) region of birth (accumulated migration) of in-migrants, b) last region of residence (12 months before migration to Rondonia) of in-migrants, c) percentage of individuals engaged in off-farm employment. Unfortunately there is no information on internal and international emigration of individuals from farm households from 1985 to 1995, restricting our analysis to 2010. However, there are reasons to believe that these figures are negligible (except for the case when the whole households move given land turnover or abandonment). Initial phases of frontier settlement have some distinct features which

characterizes strong pull migratory factors: i) high farm labor demands in initial stages of settlement, ii) the stage in the household life cycle characterized by young ages of the head and spouse and high youth dependency ratios which defines a small stock of adult individuals at high migration risk, iii) incipient regional urbanization and precarious infrastructure (communications, transportation system, electricity) which create high costs and constrains to mobility as well as small accessibility to labor markets elsewhere.

*Clusters of livelihoods, mobility and lifecycles using Latent Class Models.* We test the predictive ability of household life cycle markers for studying livelihoods and mobility strategies over frontier development using latent class cluster models with covariates.

Latent class clustering is a technique of statistical profiling for a set of variables when the latent variable is intrinsically categorical. The objective is to identify the *structure of cases* instead of the structure of variables, as in factor analysis (Lazarsfeld and Henry, 2008; Clogg and Goodman, 1984). The model classifies the elements in mutually exclusive classes in relation to the latent structure. Individual class membership to multiple profiles, in probabilistic terms, is also calculated, approximating the model from fuzzy techniques such as the Grade of Membership model (Manton et al., 1994). These classes are defined by a criterion of conditional independency, in which each observed variable is statistically independent of all other variables within the latent class (Lazarsfeld and Henry, 2008). Thus, once identified the latent structure (the number of clusters), there should be no association left between any pair of variables used in the model.

One of the objectives of latent class analysis is to identify a model with the smaller amount of classes that describe the data (Hagenaars and McCutcheon, 2002). The model initially assumes the identification of only one group, and subsequently compares the fit of the model when the number of groups increasing to 2, 3, until *n* groups. The advantage of this technique in relation to other clustering techniques is that the choice of number of classes is based on a statistical model which can be tested, thus reducing the arbitrariness in the choice of the ideal number of groups (Magidson and Vermut, 2002).

Formally, the model assumes that a) each observation (in our case, farm households) belongs to only one latent class, and b) each observed variable is independent of all others conditional to the membership to the latent class. Thus, the model can be represented by a combination of the unconditional probability that each element belongs to a specific class, and by the conditional probabilities of response to the manifested (indicator) variables, given the latent class to which the observation belongs. This assumption is known as the *local independence assumption*. Because sometimes bivariate association of residuals is present after controlling for the latent variable, some authors suggest two different correctional steps: increase the number of classes, or allow residuals to be associated (known as direct effects). The latter is always preferred, since it is less parametrized. Wald tests of significance are used in addition to the bootstrap chi-square to test if they are valid as a model adjustment strategy. All direct effects in this paper were statistically significant, dramatically improving model fit.

We use two different types of variables in the cluster models: indicator variables (for clustering definition), and active covariates (for the conditional probabilistic classification of cases to each latent class category). In order to measure our latent variable as livelihood strategies we apply the livelihood dimensions suggested by the literature (Bebbington, 1999; Sherbinin et al., 2008; VanWey et al., 2012). The indicator variables are: human capital (educational attainment of the household head, educational attainment of the spouse, occupational mobility through off-farm employment of at least one household member); physical capital (ownership of holdings, plot size, cattle ownership and amount of forest in the plot); natural capital (good accessibility to on plot water, plot with rubber trees and Brazilian nuts); financial capital (per capita household income, % of income from agricultural and not

agricultural; if household receives any public cash benefit); social capital (using as proxies family structure: nuclear family versus multigenerational family); mobility (place of birth and previous state of residence before moving to Rondonia), % of household members born in Rondonia, number of international outmigrants from the household, number of inmigrants in the household). To keep model as simple and parsimonious as possible since estimation procedure is data demanding (rapid increase of number of parameters as number of clusters increase, and maximum likelihood based on asymptotic theory of consistency and efficiency) we use only markers of household life cycle as covariates: age of the household head, household size, household dependency ratio, and number of years living in Machadinho.

We compare three modeling strategies: Strategy 1 (S1), with a minimum set of comparable variables for years 1985, 1986, 1987 and 1995. The predictors are the three lifecycle markers (age of household head, household size, and household dependency ratio). Strategy 2 (S2) brings a maximum set of comparable variables for years 1987 and 1995 and adds as predictors, related to S1, a variable measuring the household head´s time of residence in Machadinho. Finally, Strategy 3 (S3) uses the same lifecycle predictors as in S2 and includes more specific mobility variables for year 2010 only.

Strategy S1 gives a general sense of how livelihood strategies and life cycle indicators predict membership to different livelihoods as frontier evolved over time. Although limited to test plot life cycle, we can have a sense of how membership to different livelihoods strategies change as household age (age effect), and how aging effect changes as frontier evolves (frontier development stages interacting with household life cycle). Predicted probabilities were estimated using the Lowess smoothing technique for all observations with a Cook's Distance measure for residuals smaller than 4 times the number of parameters divided by the number of observations in the analytical sample (as suggested by Magidson and Vermunt, 2002).

Strategy S2 compares sensitiveness of estimated results from S1 when more indicator variables for livelihood strategies and for life cycle variables, available for 1987 and 1995 only – compared to 1985 and 1986 – were included in the models. S2 also includes a variable measuring for how long the household head has continuously lived in Machadinho, thus approximating a cohort effect of life cycle. Finally, strategy S3 refers to the 2010 model where additional mobility measures, only available for this year, were included: number of households with out-migrants or international emigrants since 1995.

## Results

*Descriptive analysis*

Table 1 confirms documental reports on the colonization of Machadinho and census data in terms of the prevalence of southerners and southeasterners by birth or last migration stage before Rondonia in the first stages of colonization. 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) and the inter-regional accumulated migration decreases. The proportion of individuals born in the Southeast remains relatively stable over time and increases its representation as the last region of residence.

Table 2 shows information on international emigration and out-migration for 2010 as well as off-farm employment. As suggested before, we assume that emigration and out-migration from farm households is negligible in the region before 1995 (except by whole family migration due to plot turnover or land abandonment). Given the characteristic of migration as a rare population event, it is outstanding the high proportion of farm households with out-migrants (59.8%) or international emigrants (13.5%) – reflecting the maturation of life cycle events

(children leaving adulthood and leaving home). The United States is the main destination of these migrants (32%), followed by the rural frontier in Paraguay (30%), and Portugal and Spain (24%).

Together with internal and international migration, the high proportion of households with at least one member in off-farm employment (34.7%), and of households adopting both out-migration and international emigration (22%) shows that population mobility is an important component of livelihood strategies in Machadinho. Almost 5% of farm households have members engaged in the three types of mobility.

Table 1 - Region of birth and last region of residence of household members - Machadinho D´Oeste, 1985, 1986, 1987, 1995 and 2010[a]

| | 1985 | | 1986 | | 1987 | | 1995 | | 2010 | |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Region of Birth*** | N | % | N | % | N | % | N | % | N | % |
| North and Center West | 359 | 26,5 | 785 | 28,8 | 1173 | 29,9 | 2042 | 40,7 | 426 | 46,9 |
| South | 494 | 36,4 | 910 | 33,4 | 1326 | 33,8 | 1192 | 23,7 | 145 | 16,0 |
| Northeast | 135 | 9,9 | 291 | 10,7 | 410 | 10,5 | 505 | 10,1 | 67 | 7,4 |
| Southeast | 365 | 26,9 | 729 | 26,8 | 1001 | 25,5 | 1280 | 25,5 | 268 | 29,5 |
| Other country | 4 | 0,3 | 8 | 0,3 | 9 | 0,2 | 2 | 0,0 | 2 | 0,2 |
| Total | 1357 | | 2723 | | 3919 | | 5021 | | 908 | |
| ***Previous Region (12 months before Rondonia)*** | | | | | | | | | | |
| Rondonia State | 2 | 0,2 | 16 | 0,6 | - | - | - | - | 10 | 3,9 |
| North and Center West | 339 | 25,6 | 736 | 27,2 | 1007 | 25,8 | 1179 | 23,7 | 56 | 21,7 |
| South | 589 | 44,4 | 1168 | 43,2 | 1712 | 43,9 | 1994 | 40,0 | 94 | 36,4 |
| Northeast | 91 | 6,9 | 160 | 5,9 | 265 | 6,8 | 369 | 7,4 | 16 | 6,2 |
| Southeast | 290 | 21,9 | 569 | 21,1 | 801 | 20,5 | 1324 | 26,6 | 80 | 31,0 |
| Other country | 15 | 1,1 | 54 | 2,0 | 119 | 3,0 | 113 | 2,3 | 2 | 0,8 |
| Total | 1326 | | 2703 | | 3904 | | 4979 | | 258 | |

[a] In 2010, the variable of previous region was measured only for the household head.

Source: Machadinho Dataset (1985, 1986, 1987, 1995, 2010)

Table 2 - Percentage of farm households with migrants and individuals in off-farm employment in Machadinho D´Oeste - 2010

| ***Mobility status in households*** [a] | N | % |
|---|---|---|
| (1) Households with out-migrants (1995-2014) | 155 | 59,8 |
| (2) Households with international emigrants (1995-2014) | 35 | 13,5 |
| (3) Households with individuals in off-farm employment | 90 | 34,7 |
| (1) + (2) = households with both internal out-migrants and international emigrants | 27 | 10,4 |
| (1) + (3) = households with both internal out-migrants and off-farm emplyment | 57 | 22,0 |
| (2) + (3) = households with both international emigrants and off-farm employment | 14 | 5,4 |
| (1) + (2) + (3) = households with internal and international migrants and off-farm employment | 12 | 4,6 |

[a] considering the total number of households in 2010 = 259

Source: Machadinho Dataset (2010)

Table 3 shows dimensions and variables to evaluate farm household life cycle and livelihood strategies at each stage of frontier development. It pools together, at each survey year, different cohorts of year of arrival in the frontier. As expected, 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 the household dependency ratio. Also mirroring the advanced process of demographic transition in Brazil, household size becomes increasingly small compared to earlier years. In association with the larger penetration of the Brazilian welfare state, these older households have a high share of their incomes in governmental cash transfer programs in 2010 and specialization on less-demanding labor activities. Furthermore, the overall level of human capital increases significantly over time as indicated by the education of the household head.

Table 3 - Descriptive statistics: sample, markers of household life cycle, household composition of capitals in Machadinho D´Oeste – 1985, 1986, 1987, 1995 and 2010

| | | | | Survey | | |
|---|---|---|---|---|---|---|
| Dimension of analysis | Variable | 1985 | 1986 | 1987 | 1995 | 2010 |
| | Number of farm households | 284 | 568 | 808 | 1069 | 259 |
| Sample characteristics | Number of individuals in the plot | 1697 | 2762 | 3961 | 5031 | 914 |
| | Mean household size | 6.0 | 4.9 | 4.9 | 4.7 | 3.5 |
| | Dependency ratio [a] | 1.04 | 0.89 | 0.87 | 0.77 | 0.82 |
| | mean age of head of household (years) | 39.3 | 39.9 | 39.9 | 42.3 | 52.2 |
| Markers of farm household | mean age of spouse of the head (years) | 33.5 | 33.3 | 34.2 | 35.9 | 45.7 |
| household life cycle | land in pasture (%) | 73.6 | 27.2 | 13.4 | 33.9 | - |
| | land in annuals and perennials (%) | 12.6 | 51.1 | 80.6 | 50.7 | - |
| | farm households hiring laborers (%) | - | 30.8 | 29.8 | - | 44.0 |
| | heads with more than 4 years of education (%) | 22.9 | 20.2 | 14.9 | 33.0 | 66.4 |
| Human Capital | spouses with more than 4 years of education (%) | 21.1 | 16.8 | 14.7 | 32.3 | 76.6 |
| | % individuals over 14 y.o. in off-farm employment | 5.2 | 12.9 | 9.3 | 6.7 | 16.8 |
| | sex ratio | 1.3 | 1.3 | 1.3 | 1.3 | |
| | farm households owning cattle (%) | - | 6.9 | 14.1 | 64.5 | 85.3 |
| | head own the plot in Machadinho (%) | 90.4 | 99.1 | 88.3 | 76.7 | 90.2 |
| Physical Capital | own other rural plots (%) | - | 16.1 | 8.3 | 20.2 | 32.4 |
| | ownership of land / house in the city (%) | - | - | 16.5 | 13.0 | 15.7 |
| | % income from on farm production[c] | - | - | 8.9 | 77.1 | 70.1 |
| Financial Capital | households receiving government cash transfers (%) | - | - | - | - | 56.0 |
| | households with credit or loans (%) | - | - | - | 20.7 | 47.3 |
| | households receiving support from out-migrants (%) | - | - | - | - | 17.4 |
| | land in primary forest (%) | 13.3 | 21.8 | 6.2 | 16.1 | - |
| Natural capital | households with good accessibility to water (%)[d] | 17.8 | 40.1 | 54.6 | 77.6 | 83.6 |
| | households with extractive products (%)[e] | - | 30.6 | 24.6 | 18.4 | 9.7 |
| | heads born in South/Southwest Brazil (%) | 65.6 | 65.9 | 67.1 | 70.4 | 70.5 |
| | households with out-migrants in the last 5 years (%) | - | - | - | - | 30.1 |
| Social capital | households with at least one international out-migrant (%)[f] | - | - | - | - | 13.5 |
| | nuclear family - parents and sons only (%) | 74.0 | 83.2 | 80.5 | 84.4 | 76.4 |
| | multigenerational household (%)[g] | 9.1 | 3.9 | 4.7 | 5.8 | 14.2 |
| | plots with other households (%) | - | - | 19.3 | - | 32.6 |

[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.
[a] These variables are simultaneously markers of stage in farm household life cycle and indicators of physical capital.
[b] Qualitative estimates from field observations.
[c] Includes income from agriculture (annuals and perennials) and animals (pigs, chickens, horses etc) rather than cattle (about this last, see footnote a).
[d] Well in the plot, pumped water or piped water. In 2010 this variable was estimated from The Brazilian 2010 census data.
[e] It refers, berore 2010, to the existence of seringas (rubber tree); in 2010, to seringas, apiculture and fish ponds.
[f] Living at the household or abroad at the date of survey. Total of 50 international out-migrants identified, in 35 households.
[g] Farm households cohabited by at least grandsons and grandparents.

Source: Machadinho Dataset (1985, 1986, 1987, 1995, 2010)

Farm households at later stages in the frontier adopt more profitable land use strategies based on cattle-raising. This seems to be related to their smaller family size in accordance to the stage in their demographic life cycle, and because annuals and perennials

are more labor demanding. While on-farm activities remain the main source of income, 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 not measured for years rather than 2010), and higher number of off-farm labor hired. 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 reaches a peak in 1995 (77% on average) and decreases to 70% in 2010, when off farm income diversification increases its importance.

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, as well as assure income flows for older parents (through pensions) or the younger ones (from governmental programs such as *Bolsa Familia*).

Except for the first year of analysis (1985) when a greater share of land in pasture may indicate that the first colonizers settled larger plots of land and forest was converted in pasture initially for later use in annual and perennials, subsequent land uses – and particularly between 1987 and 1995 - suggest an expected trajectory from farm household lifecycle theories in terms of increasing land converted from annuals and perennials to pasture. Over time there is also a substantial increase in the proportion of far households with cattle, what is expected from theory.

These findings allows us to hypothesize that demographic dynamics and land use in Machadinho reinforce independence of plot/land use life cycle related to household life cycle as suggested by other studies (Barbieri et al, 2005; Barbieri 2006; Guedes 2010). The independence and speed of household and plot life cycle transitions in Machadinho may be accelerated due to i) higher market integration fostering mobility, ii) the role of institutions affecting rural livelihoods (urban bias, cash transfer programs, infrastructure building which fosters rural out-migration), and iii) more advanced demographic transition and multi-generational cohabitation patterns (as indicated by the proportion of plots with other households and plots with vertically extended families). In contrast, higher reliance on more profitable land use - off-farm employment, out-migration and cash transfer programs – may decrease reliance on natural capital as source of farm household income, as indicated by the decreasing share of land on forest and extractive activities. Nonetheless, increasing population mobility in the Amazon has resulted in a pattern which challenges a simple dichotomy between “rural” and “urban”. In Machadinho, an important proportion of farm households have a home in the local town (around 16% in 2010), and the share of individuals engaged in off-farm employment and out-migration reinforce this characteristic

*Clusters of Livelihoods: Latent Class Models*

Table 4 shows tests of significance for estimated parameters of indicators and covariates for Strategy 1 (long run comparison of livelihood strategies using a minimum set of comparable variables in 1985, 1986, 1987 and 1995). It also presents the Coefficient of Determination for each indicator of the Latent Cluster Models. The Wald and p-value tests indicate the significant variables at each year (1%, 5%, and 10%), representing the variables that are significantly different across latent classes. The $R^2$ measure indicates the degree in which the variance of a variable is explained by the latent variable. Tables 5 and 6 bring the same tests of significance for strategies 2 (1987 and 1995) and 3 (2010).

As suggested by Model Fit in Tables 4, 5 and 6, most indicators and covariates were significant to differentiate classes of livelihoods. Regarding S1, it can be seen that population mobility variables gains explanatory power over time for differences in livelihood strategies.

Human capital is also important to explain livelihood differences. Natural capital loses explanatory power over time, while off-farm employment overweighs on-farm production for livelihood differences over time. Overall, these results allow us to confirm that household portfolio shifts its composition over time towards a higher importance of human and financial capitals.

This result is corroborated by Strategy 2, which allows a comparison of a larger set of indicator variables for livelihood strategies and for life cycle variables in 1987 and 1995.There is an increasing importance of off-farm employment as a livelihood strategy over time as well as increasing importance of financial capital, especially income from off-farm employment. Previous migration and origins also keep their importance to discriminate livelihood strategies. Both household and frontier life cycles (this last being measured by the time living in Machadinho) are important discriminators of livelihood strategies, and Natural Capital continues to loose predictive power over time, especially forest stock (both primary and secondary).

Finally, Strategy 3 (2010) suggests that off-farm employment and financial capital keep their dominance (as suggested by S1 and S2) in terms of predictive power for livelihood strategies in advanced stages of frontier development. Regarding mobility strategies, place of birth and the percentage of individuals in the household born in Rondonia are important indicators to explain differences between strategies. This is particularly the case of the last, given the internalization of mobility dynamics within the frontier - as expected by second and third generations already being born locally. Furthermore, households with out-migrants or international emigrants are also important indicators to differentiate livelihood strategies in 2010. Except for in frontier life cycle (time living in Machadinho), other life cycle markers keep their importance in 2010.

It is outstanding the high proportion of farm households with out-migrants or international emigrants and proportion of households with at least one member in off-farm employment in 2010. However, as shown by the fit statistics in table 6, they are not as important to discriminate livelihoods compared to place of birth, previous region and off-farm employment. Nonetheless, it is clear that across different types of livelihoods, migration is a widespread strategy in the region with distinct results regarding the household composition of capitals. Thus, livelihoods which involve distinct mobility strategies become a key aspect of portfolio changes towards a higher prevalence of financial and social capital vis-a-vis capitals more related to on-farm production (physical and some components of the human capital).

The discrimination power of the estimated latent variable (livelihood strategy) explains observed variation in human capital – particularly education – only in the initial frontier settlement (1985 in S1), with significance but at a lower level in the mature frontier (1995 in S1 and S2), and with no significance in 2010 (S3). These human capital variables are taken over by mobility strategies (including off-farm employment) and financial capital in later stages of frontier development. While life cycle markers keep their discrimination power at early and mature frontiers (1985 in S1, 1987 and 1995 and S1 and S2), they seem to lose power over time as predicted – this is particularly the case of household size and dependency ratio, with a smaller significance at later stages (2010). Finally, cohabitation patterns (nuclear and multigenerational families) are relevant to explain livelihood strategies mostly at intermediate stages of frontier development (1995 in S1 and S2), and in 1987 in S1. While it loses power in 2010, the still significance (at a lower level) only for multigenerational families may be related to the importance of this family strategy to release young farm labor to off-farm employment or migration strategies.

Table 4 – Test of Significance for Estimated Parameters and Indicators and Covariates Coefficient of Determination for Latent Cluster Models - Machadinho, 1985 to 1995[a], Strategy 1

| | | | | Wald Test[b] | | | | $R^2$ | |
|---|---|---|---|---|---|---|---|---|---|
| Dimension | Variables (Indicators and Covariates) | 1985 | 1986 | 1987 | 1995 | 1985 | 1986 | 1987 | 1995 |
| Human Capital | % household heads with more than 4 years of education | 13,06** | 1,77 | 3,61 | 18,16*** | 0,03 | 0,01 | 0,01 | 0,01 |
| | % household head´s spouses with more than 4 years of education | 17,84*** | 4,17 | 15,68** | 13,74** | 0,11 | 0,02 | 0,03 | 0,03 |
| | Prop. individuals in off-farm employment (14 y.o. or more) | 21,54*** | 767,81*** | <0,01 | >10.000*** | 0,89 | 0,71 | 0,84 | 0,84 |
| Physical Capital | Own interviewed plot | 21,68*** | 59,25*** | 12,54* | 26,95*** | 0,04 | 0,01 | 0,01 | 0,07 |
| Financial Capital | Land in pasture (Ha) | 26,73*** | 116,27*** | 8485,43*** | >10.000*** | 0,43 | 0,38 | 0,12 | 0,04 |
| | Land in crops/perennials (Ha) | 125,16*** | 68,98*** | 327,56*** | 479,55*** | 0,78 | 0,14 | 0,23 | 0,07 |
| | Good on site accessibility to water | 3,59 | 11,43** | 44,71*** | 11,83* | 0,02 | 0,03 | 0,05 | 0,01 |
| Natural Capital | Plot deforested (Ha) | 64,31*** | 12,79** | >10.000*** | 1200,07*** | 0,89 | 0,02 | 0,05 | 0,25 |
| | Secondary Forest (Ha) | 26,73*** | 109,48*** | 462,88*** | 4335,62*** | 0,08 | 0,37 | 0,61 | 0,10 |
| Social Capital | Nuclear family | 5,78 | 8,34 | 15,78** | 12,59** | 0,03 | 0,02 | 0,03 | 0,01 |
| | Multigenerational family | 3,95** | 1,72 | 23,85*** | 33,28*** | 0,02 | 0,00 | 0,04 | 0,01 |
| Mobility | Previous state of residence | 104,87*** | 23,69* | 29,87* | 64,17*** | 0,07 | 0,08 | 0,01 | 0,02 |
| | Region of birth | 27,89** | 1289,03*** | 28,96 | 227,15*** | 0,03 | 0,14 | 0,01 | 0,02 |
| | % of individuals in household from Rondonia | 21,54*** | To infinity*** | 33,83*** | 3022,50*** | 0,03 | 1,00 | 0,02 | 0,57 |
| Life Cycle | Household size | 20,58*** | 3,88 | 24,93*** | 60,82*** | - | - | - | - |
| | Age of the household head (mean) | 15,45*** | 6,73 | 23,08*** | 103,52*** | - | - | - | - |
| | Dependency Ratio[c] | 76,4*** | 8,87 | 17,07** | 95,71*** | - | - | - | - |
| Sample size | Sample size | 124 | 408,00 | 582 | 725 | | | | |

Source: Machadinho Dataset (1985, 1986, 1987, 1995, 2010)

[a] Bootstrapped standard errors for Likelihood Difference test for number of clusters

Robust standard errors for test of signficance for variables

Robust model coefficients (Cook's Distance criterion)

[b] p-value: p<1% (***), 1<p<=5% (**), 5%<p<=10% (*)

[c] Given by the 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.

Table 5 - Test of Significance for Estimated Parameters and Indicators and Covariates Coefficient of Determination for Latent Cluster Models – Machadinho, 1987 and 1995[a], Strategy 2

| Dimension | Variables (Indicators) | Wald Test[b] | | $R^2$ | |
|---|---|---|---|---|---|
| | | 1987 | 1995 | 1987 | 1995 |
| Household Life Cycle | Educational attainment of the household head (mean) | 24,87*** | 13,69* | 0,01 | 0,03 |
| | Educational attainment of the household head's spouse (mean) | 30,28*** | 12,60*** | 0,04 | 0,03 |
| | Individuals in off-farm employment (proportion age 14 or more) | 468,75*** | >10.000*** | 0,71 | 0,79 |
| Physical Capital | Own interviewed plot | 101,75*** | 24,22*** | 0,03 | 0,05 |
| | Own other rural plot | 30,8 | 19,94*** | 0,01 | 0,03 |
| | Own urban plot | 82,63*** | 6,25*** | 0,09 | 0,01 |
| | Farm households owning cattle | 17,56** | 13,57* | 0,02 | 0,03 |
| | Rural and urban properties | 105,73*** | 57,00*** | 0,03 | 0,04 |
| Natural capital | Good on site accessibility to water | 16,75** | 8,08 | 0,04 | 0,01 |
| | Access to rubber trees | 24,16*** | 11,84 | 0,01 | 0,02 |
| | Plot deforested (Ha) | 9 | 35,86*** | 0,19 | 0,16 |
| | Secondary Forest (Ha) | 252,25*** | 497,55*** | 0,52 | 0,07 |
| Financial capital | Income per capita (mean R$) | 315,746*** | 262,79*** | 0,33 | 0,27 |
| | Income from off-farm sources (%) | 4867,22*** | 239,56*** | 0,08 | 0,54 |
| | Land in pasture (Ha) | 305,74*** | 787,33*** | 0,20 | 0,06 |
| | Land in crops/perennials (Ha) | 203,53*** | 32,03*** | 0,29 | 0,04 |
| Social capital | Nuclear family | 44,53*** | 28,79*** | 0,04 | 0,02 |
| | Multigenerational family | 6,43 | 55,65*** | 0,04 | 0,02 |
| Mobility | Region of birth | 34,13** | 112,45*** | 0,02 | 0,02 |
| | Previous state of residence | 111,03*** | 49,92*** | 0,02 | 0,01 |
| | % of individuals in HH from Rondonia | 468,75*** | 7249,62*** | 0,08 | 0,27 |
| Life cycle | Household size | 40,42*** | 17,43** | - | - |
| | Time living in Machadinho (years) | 16,349** | 19,15*** | - | - |
| | Age of the household head (mean) | 41,25*** | 50,33*** | - | - |
| | Dependency ratio[c] | 16,49** | 37,94*** | - | - |
| Sample size | Sample size | 428 | 718 | | |

Source: Machadinho Dataset (1985, 1986, 1987, 1995, 2010)

[a] Bootstrapped standard errors for Likelihood Difference test for number of clusters. Robust standard errors for test of signficance for variables. Robust model coefficients (Cook's Distance criterion).

[b] p-value: p<1% (***), 1<p<=5% (**), 5%<p<=10% (*)

[b] Given by the 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.

Table 6 - Test of Significance for Estimated Parameters and Indicators and Covariates Coefficient of Determination for Latent Cluster Models – Machadinho D'Oeste, 2010[a], Strategy 3

| Dimension | Variables (Indicators) | Model Fit[d] | |
|---|---|---|---|
| | | Wald Test[e] | $R^2$ |
| Human Capital | Educational attainment of the household head (mean) | 7,98 | 0,02 |
| | Educational attainment of the household head's spouse (mean) | 8,06 | 0,04 |
| | Individuals in off-farm employment (proportion age 14 or more) | 242,85*** | 0,60 |
| Physical Capital | Own interviewed plot | 113,38*** | 0,07 |
| | Own other rural plot | 8,01 | 0,01 |
| | Own urban plot | 1,37 | 0,02 |
| | Farm households owning cattle | 9,89* | 0,02 |
| | Rural and urban properties | 105,98*** | 0,03 |
| Natural capital | Access to rubber trees | 12,59** | 0,06 |
| Financial capital | Income per capta (mean R$) | 243,30*** | 0,70 |
| | Income from off-farm sources (%) | 514,03*** | 0,79 |
| | Household with government cash transfer | 23,57*** | 0,03 |
| Social capital | Nuclear family | 7,22 | 0,04 |
| | Multigenerational family | 12,5** | 0,04 |
| | Region of birth | 1366,33*** | 0,25 |
| Mobility | Previous state of residence | 95,53*** | 0,08 |
| | % of individuals in HH from Rondonia | 17,75*** | 0,98 |
| | Households with out-migrants (0/1) | 7,89*** | 0,03 |
| | Households with international migrants (0/1) | 24,58*** | 0,07 |
| Life cycle | Household size | 12,86** | |
| | Time living in Machadinho (years) | 2,45 | |
| | Age of the household head (mean) | 17,36*** | |
| | Dependency ratio[c] | 22,82** | |
| Sample size | Sample size | 207 | |

Source: Machadinho Dataset (1985, 1986, 1987, 1995, 2010)

[a] Bootstrapped standard errors for Likelihood Difference test for number of clusters.

Robust standard errors for test of signficance for variables.

Robust model coefficients (Cook's Distance criterion).

[b] p-value: p<1% (***), 1<p<=5% (**), 5%<p<=10% (*)

[c] Given by the 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.

[d] Bootstrapped standard errors for Likelihood Difference test for number of clusters. Robust standard errors for test of signficance for variables. Robust model coefficients (Cook's Distance criterion).

[e] p-value: p<1% (***), 1<p<=5% (**), 5%<p<=10% (*)

*Discussion*

Overall, the descriptive statistics and the cluster models show that while life cycle markers keep their discrimination power at early and mature frontiers, they seem to lose power over time, especially in 2010. As suggested by the literature review, the integration to markets and contextual factors such as the advancement of cash transfer programs, and more advanced demographic transition and multi-generational cohabitation seems to disrupt the endogeneity between household and plot life cycles as predicted by the literature. In this sense, the social profile of farmers, as represented by their mobility histories, settlement history and the connection networks of the frontier with other frontiers and urban markets (through, e.g., off-farm employment and urban plots) determine the characteristics and the pace of change in each phase.

Moreover, the increase in human capital particularly for younger household heads and spouses (because of the universalization of primary and to a lesser extent secondary school in Brazil) create a higher selectivity profile for this group of colonists (together with the younger age per se) for urban markets. Cash transfer programs (mainly the conditional transfer *Bolsa Familia* and the retirement income among multigenerational and older households) may be one additional element to increase financial capital of wealthier households, increase income security, minimize risk, and consequently incentive households to pursue income and welfare maximization specially form off-farm activities.

As the frontier ages and the second generation of colonists become relatively larger, the proportion of natives from the Northern region increases. However, despite the higher heterogeneity and proportion of natives in the population, migration history persists as a key element discriminating livelihoods and ultimately distinguishing successful colonists over frontier development.

Population mobility variables (place of birth, previous migration and off-farm employment) gains explanatory power over time (1987 to 2010) for differences in livelihood strategies, and this seems related to shifting household portfolio composition. However, and despite the fact that more market-oriented strategies at later stages of frontier development redefine livelihoods, some specific household structures with migration history from Southern Brazil continue to derive some livelihood from subsistence agriculture *together with* mobility strategies.

**Conclusions**

In this paper we discuss how population mobility into, within, and from the Brazilian Amazonia over time may be explained by the changing demographic composition, their access and diversification of sources of livelihoods as well as stages and evolution of frontier settlements.

We suggest that live cycle effects loose significance in 2010 and over time due to higher importance of *frontier* life cycle, which provides higher payoffs as a place-specific capital to improve returns from a specific livelihood strategy. Migration history and mobility variables are, on the other hand, key dimensions distinguishing livelihoods in the frontier. Over time, mobility may represent a pressure over natural resources of the region, due to rural-rural migration, which usually results in further deforestation, and rural-urban mobility which puts increasing demands on urban infrastructure and budgets. However, the former can be ameliorated by appropriate settlement and agricultural policies, and the latter by appropriate urban planning.

Overall, the highest levels of income and welfare are associated with households which diversify their livelihoods particularly in terms of capitals and adopt mobility strategies as a key component of this livelihood diversification. These mobility strategies may also be facilitated by a growing connectivity of rural-urban areas (in terms, for example of families owning urban land, dual-residency, and growing market-oriented land uses). At last, capital diversification, mobility, and welfare may explain the correlation between older households and lower levels of relative wellbeing. Despite the literature anecdotal stories on the survival of stronger in the frontier (Barbieri et al., 2016), the oldest may survive in the frontier with deprived levels of capitals since more profitable migration strategies are income-selective (see further evidences in Barbieri et al., 2016). On the other hand, younger households in the frontier are a selective group, with more complex mechanisms for income generation, since they are entering a more urbanized and market-oriented frontier, which requests higher levels of human capital.

Besides micro-level (household/plot) dynamics, population mobility as a component of livelihoods over time also responds to broader institutional changes affecting farmers'

perceived returns to their capital stocks. The advancement and (virtually) universalization of cash-transfer programs in Brazil seem to affect drastically the perceived returns of on-farm production especially in older households with labor scarcity. In this way, older households with labor shortage are, according to life cycle theories, likely to have their land use and farm household labor allocation affected, with out-migration being responses as well as farmers seeking to acquire cattle for other reasons, freeing up labor, which facilitates out-migration of circular mobility (off-farm employment). As a matter of fact, the descriptive results show that farm households at later stages in the frontier adopt more profitable land use strategies based on cattle-raising (probably combined with off-farm employment), what seems related to their smaller family size in accordance to the stage in their demographic life cycle, and because annuals and perennials are more labor demanding.

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