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Education and Transitions: A Multi-State Markov Model of the Brazilian Labor Market

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Abstract

This study analyses the Brazilian labor market using time-homogeneous Markov processes. Estimates of continuous-time transition rates from panel data over the period 2017-2019 indicate the instantaneous risk of moving from one labor market state to another for different age and gender groups. The states are formal and informal employment, self-employment, unemployment and inactivity. A proportional hazards model links the transition intensities to educational covariates, providing evidences of the role of education on labor market mobility patterns. The results suggest that the younger and the older, female and the least educated workers flow out of the labor force more intensely than other groups. Higher education seems to prevent unemployed workers from entering the informal sector more than it helps them transition into formal positions. Informality appears as a port of entry for low educated young workers, who face barriers of entry into formality and self-employment. There is little evidence of asymmetry of flows between formality and informality that would characterize the segmentation of the labor market, especially for highly educated workers.

Keywords: Labor market, Transitions, Markov model, Education, Mobility

Resumo

Este estudo analisa o mercado de trabalho brasileiro utilizando processos de Markov homogêneos. As estimativas das taxas de transição em tempo contínuo, obtidas a partir de dados em painel para o período 2017-2019, indicam o risco instantâneo de um trabalhador sair de um estado para outro. Os estados considerados são de emprego formal, emprego informal, emprego por conta própria, desemprego e inatividade. As taxas de transição foram calculadas para diferentes grupos de idade e gênero. Um modelo de riscos proporcionais foi utilizado para relacionar as taxas de transição a variáveis educacionais, permitindo avaliar da associação entre os níveis de escolaridade e padrões de mobilidade no mercado de trabalho. Os resultados indicam que os fluxos de saída da força de trabalho são mais intensos entre os mais jovens e os mais velhos, entre as mulheres e entre os menos escolarizados. Uma maior escolaridade está associada a taxas de saída do desemprego para a informalidade menores, ao mesmo tempo que pouco se associa a maiores fluxos para o setor formal. O setor informal aparece como porta de entrada no mercado de trabalho principalmente para os jovens de menor escolaridade, que enfrentam barreiras à entrada no setor formal e conta-própria. As evidências são escassas em relação à assimetria dos fluxos entre os setores formal e informal prevista pela hipótese da segmentação do mercado de trabalho.

Palavras-chave: Mercado de trabalho, Transições, Modelo de Markov, Educação, Mobilidade

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1 Introduction

The stock of workers in different labor market states is the basis of official indicators such as the unemployment and the labor force participation rates. The observation of snapshots of such ratios, however, may mask some of the dynamics of the labor market. Movements in the stock variables are a result of the interaction of several flows of individuals in and out of different states. Specific demographic groups display distinct outcomes in terms of employment and participation as well as mobility. Women and younger workers are often found in situations of instability or lower attachment to the labor force, which translates into a higher mobility between employment and non-employment. The highly educated are usually the ones holding the most stable jobs and the least likely to flow into unemployment or into the informal sector. This study examines transition rates between five labor market states for Brazilian men and women of different age groups considering education as an explanatory variable.

The availability of longitudinal data on individual labor market statuses has contributed to the development of the empirical literature on labor market transitions and mobility. The main contribution of this study is the estimation of a continuous-time model of the Brazilian labor market using panel data available from the *Pesquisa Nacional por Amostra de Domicílios Contínua* (PNADC) between 2017 and 2019. Individual labor market states are observed quarterly over the course of a year, providing up to five consecutive, equally spaced observations of labor states. Such labor paths are assumed to be the realization of an underlying continuous-time homogeneous Markov process. Three distinct employment states (formal salaried, informal salaried and self-employment) and two non-employment states (unemployment and inactivity) compose the state-space of the model. Discrete-time transition probabilities calculated from panel data often miss transitions that occur within the interval between observations. The longer the time elapsed between two observations of a worker, the higher the chances that a transition occurs in the meantime without being recorded. Reduced-form estimates of continuous-time transition intensities documented in this study have the advantage of indicating the instantaneous risk of moving between states. The continuous-time framework also provides estimates of the mean duration of a spell in each state.

The discrimination of the employment state into three distinct categories, expanding the state-space to five states, is due to the importance of the informal sector in developing countries and the need to distinguish it from the self-employment state. In Brazil, a third of all employees were uncovered by labor regulations and laws, and therefore informally employed in both the private and public sectors, in 2019. Considering the entire employed population, the share of workers holding informal jobs plus the self-employed who do not

comply with the law and the unpaid workers reached 41 percent in 2019 according to data from the Brazilian Institute of Geography and Statistics (IBGE). Because informal jobs are uncovered by the labor legislation, they are often thought of as more precarious than their formal counterparts. Empirical evidence suggest that informal jobs are easier to find, but the duration of an employment spell is longer in the formal sector. Therefore, turnover rates in the informal sector are usually higher compared to the formal sector, which may be associated with the lower wages of informal positions. Mobility patterns, together with the analysis of wage differentials, help identify whether a labor market is segmented and if different demographic groups face segmented and integrated labor markets simultaneously in an economy. The evaluation of transition rates can reveal barriers to entry in the formal sector, an expected feature of segmented labor markets.

Education is arguably one of the most important determinants of labor market outcomes and the reason why it is included as a covariate in the estimation of the transition rates. Individuals invest in education because they expect a return, mostly reflected in higher wages but also consisting of better non-pecuniary job characteristics. This return does not materialize if they are out of the labor force, which implies that workers with higher levels of education are less likely to withdrawal from the market. The opportunity cost of inactivity varies with age and gender, thus the relationship between education and transition rates differs across demographic groups. Results of the estimated model indicate that College educated Brazilian workers are half as likely to transition into inactivity from employment compared to workers with less than High School, suggesting an increased attachment to the labor force of the most educated. The effect of a High School diploma is less sizable, although it also decreases the chances of dropping out of the labor force. Education further increases female worker's attachment to the labor force, as those with High School and College degrees are also less likely to quit searching for a job and transition into inactivity.

Education is associated with the unemployment exit rates into employment. Higher educated workers may receive more job offers while they are searching for work as their formal qualifications signal their productivity. At the same time, their reservation wage is higher and therefore their chances of accepting a job offer lower. These two mechanisms have opposite effects on the transition rates out of unemployment as well as unemployment duration. I find a positive correlation between the length of an unemployment spell and education level for all age and gender groups. Education also impacts the sector in which unemployed workers enter: the most qualified workers will avoid informal positions if these are perceived as more precarious and will wait or queue for formal jobs. The estimates suggest that education prevents unemployed workers from entering the informal sector more than it helps workers transition into formal positions, as the positive effect of both degrees is not always significant for the unemployment-formality transition rates.

Informality appears to be a port of entry into employment for young Brazilian workers, who flow into this sector from unemployment more intensely than older groups. This is particularly true for the lower educated, who are the most likely to find an informal job upon search compared to the other sectors of employment. At the same time, the young are much more likely to flow back into unemployment from the informal sector, which suggests that it is relatively easy to find an informal job but the expected employment spell in this sector is very short. Formality and self-employment seem to present barriers to entry for young unemployed workers, especially if they have not completed High School. Males and females behave very similarly in their transitions into the labor market form unemployment when they are young, flowing more intensely into informality. As they age, however, unemployed males start flowing more intensely into self-employment while females continue to flow primarily into informality. Transitions into self-employment are especially intense for lower educated males coming from unemployment, which indicates that they might be trying to avoid unemployment.

As for transitions between employment sectors, if informality is perceived as a sector that offers low-quality jobs, then highly educated workers will avoid this sector, transitioning mostly into formality and between formal jobs. The less qualified workers, on the other hand, are expected to experience much longer spells of employment in the informal sector and lower transition rates into formality. However, the disadvantages of holding formal labor contracts, especially when regulation is poorly designed, may push even the most qualified workers towards informality, where the expected benefits may exceed the costs associated to the lack of legal protections. I find that a High School diploma is associated with an average 70 percent increase in the transition rate from informal to formal jobs and a College degree can more than double this rate for females. The effect is the opposite for transitions from formality to informality: highly educated workers flow less intensely into informal jobs. The higher education level is also associated with an increased flow from informality into self-employment among female workers. College educated females behave very similarly to males in their transition rates into self-employment and differently from females who have not completed High School, who are the least likely to leave the informal sector to become self-employed.

The relationship between individual characteristics and movements across different types of employment as well as non-employment sheds light on the dynamics of the labor market for particular groups of workers. The reduced form estimates of transition intensities from a continuous-time Markov model illustrate the relationship between levels of education and labor market transition rates for different age and gender groups. The results of this study help identify and characterize mobility patterns in Brazil, particularly the differences between the formal and informal sectors of employment.

2 Literature Review

2.1 Stocks and Flows of Workers

Mobility rates are one of the many outcomes explored in labor economics. The dynamics of labor markets cannot be entirely characterized by the evolution of the stocks of workers in different states. The unemployment rate, considered one of the most important labor market indicators, does not provide information on the past and future paths of workers in the labor market. A decline in the unemployment rate may be due to a large flow of individuals from unemployment into inactivity, possibly discouraged by the lack of expectations to find a job. A lower unemployment rate, in this case, does not necessarily signal an improvement in labor market conditions. On the other hand, the same decline may happen because many unemployed workers are finding new jobs and flowing into employment, which admits the opposite interpretation. Many studies in the so called "ins and outs" literature measure the contribution of the different flows to the variations in the stocks, often concerned with its behavior over the business cycle[1].

Search and matching models provide a theoretical framework that takes into account frictions in a dynamic stochastic environment, emphasizing the flows of workers between labor market states (Pissarides, 2000). The setting builds on the idea that it takes time for an unemployed worker to find an acceptable job, particularly when information is not perfectly available for all agents. In the most simple model, job seekers face search costs and receive sequential job offers (independent and identically distributed draws from a known wage distribution) at a Poisson rate. This rate may be influenced by the worker's search effort and his/her set of skills as well as market conditions. While unemployed, individuals receive a flow of non-labor income that may encompass, for example, unemployment insurance and other sources of income. Their decision to accept a job offer depends on the comparison between the payoff from accepting the job and holding it for life and the payoff from rejecting it and waiting for another offer. This decision strategy implies a reservation wage above which a job offer is accepted. The hazard rate out of non-employment combines both the job offer arrival rate and the probability that the worker will accept the offer, which in turn depends on the reservation wage.

On the other side, firms face costs to create and fill vacancies. There is asymmetry of information between worker and firm regarding the worker's productivity and there is a cost in trying to interpret the signals that workers send. When firms and workers meet,

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[1] See Darby, Haltiwanger e Plant (1986), Blanchard e Diamond (1992), Petrongolo e Pissarides (2008), Elsby, Michaels e Solon (2009), Shimer (2012), Elsby et al. (2019).

the value of their match is revealed through the sampling of the worker's productivity. Productive matches represent a transition from unemployment to employment and produce a flow of output to the firm. A random shock can terminate the match, generating a flow from employment to non-employment that can be interpreted as a layoff risk. Equilibrium wages can be determined by a bargaining process in which worker and firm bargain over the surplus created in their relationship. An alternative approach is the posting wage equilibrium, in which workers have no bargaining power and firms behave competitively when they post wage offers.

Extensions of the search model account for worker heterogeneity, endogenous offer arrival rates, on-the-job search and many others. The model can incorporate the participation margin considering the possibility that an individual is out of the labor force. Workers may differ in their opportunity cost of inactivity or the value they place on "leisure" time, as modeled by McKenna (1987). For instance, females may be less attached to the labor force because of their expected role as primary caregivers to their children and the elder, which implies that their preferences towards leisure may differ from those of males. The choice whether to search for a job stems from the comparison between the lifetime stream of leisure and the lifetime expected returns associated with the search activity. Pries e Rogerson (2009) point out that individuals with lower participation rates are also those who flow more intensely in and out of the labor force. In their three-state search model, they show that the fixed cost that non-employed individuals face when searching for a job influence their participation decision. An increase in this cost makes inactivity relatively more attractive for those who expect a shorter participation spell. Therefore, this friction discourages unemployed workers with low expected participation spells into inactivity. This is precisely the case for women and younger workers, who display both lower participation rates and higher transition rates in and out of the labor force.

Another factor that influences the behavior of workers is the education level. The investment in formal education is usually assumed to be a result of a lifetime utility maximization decision, in which higher levels of education contribute to higher earnings over the life-cycle. The opportunity cost of inactivity for highly educated workers is significant, thus they find themselves deeply attached to the labor market. In Pries e Rogerson (2009)'s framework, we could think of higher educated workers as those with longer expected participation spells and infrequent flows in and out of the labor force. As for the job search behavior, higher education could be associated with more job opportunities, reflected in a higher arrival rate of offers. At the same time, reservation wages and quality requirements are likely to be more restrictive for the more highly educated, inducing them to turn down job offers more often. The relationship between the level of education and the transition rate from unemployment to employment is therefore ambiguous (Kettunen, 1997).

Life-cycle events also change the opportunity cost of inactivity and impact the participation decision. In terms of transitions, it is expected that younger workers enter the labor force as they finish their schooling years, flowing out of inactivity more intensely than prime-age workers. At the same time, many still drop out of the labor force in order to go back to school because the cost is still low compared to the benefits. The process of entering the labor market for new workers usually involves higher mobility, either between jobs or between employment and non-employment, which translates into lower job tenure (Ryan, 2001; Nilsson, 2019). As workers accommodate in the labor market, building experience and tenure, the chances of leaving the labor force lower, reflecting an increased cost associated with inactivity. Prime-age workers are expected to be the least likely to enter inactivity and the most likely to enjoy greater stability, while older workers should be the most likely to drop out of the labor force as they reach the retirement age. In France, Fougère e Kamionka (1992) find an U-shaped transition rate into inactivity as the worker's age increases, particularly for males. For females, they find an upsurge in the rate of withdrawal from the labor force at the ages 26 to 35.

As for the sector of employment, young workers may face barriers to entry into self-employment because of credit constraints and their lower accumulated capital (Evans; Jovanovic, 1989). Maloney (1999) and Bosch e Maloney (2007) find evidences that while self-employment is not a port of entry into the labor market for the young in Latin America, informal salaried jobs might be one, particularly for the lower educated workers. In fact, Cunningham e Salvagno (2011) suggest that young workers initially flow into informality for a "stepping-stone" job and, after a short period, move to formal positions for longer spells of employment. The "job shopping" behavior of the youth is implied from their high turnover rates. As workers accumulate experience, capital and a social network over the years, many flow into self-employment. For older workers, self-employment may be perceived as a "bridge" to retirement. Kerr e Armstrong-Stassen (2011) suggest that post-career entrepreneurship can be an alternative to low wage prospects and financial necessity as well as a desire for greater independence and flexibility. The transition to retirement for older workers, much like the transition into employment for the younger, is a process that can take years and may include partial retirement or even reversals, when workers go back to the labor force before a definitive withdrawal.

The interaction between age, gender and education calls for a joint analysis of such characteristics in order to outline mobility patterns across labor market states. Royalty (1998) examines labor market mobility for young American men and women of two different education levels and finds that less educated women are more likely to transition from employment to non-employment compared to women with higher educational attainment and to men of both education levels. Highly educated women behave very similarly to men in job-to-job turnover rates. Theodossiou e Zangelidis (2009) find similar results for six European countries considering prime-age workers. Alvarez, Ciocchini e Konwar (2008)

fit a Markov model for data on the Argentinian labor market and find that education is a significant determinant of transitions. Their results suggest that females are more likely than males to transition from employment to unemployment, yet they are more likely to transition back into employment too. As expected, women tend to drop out of the labor force more intensely than men from either employment or unemployment.

2.2   Informality and the Segmentation Hypothesis

Developing countries are characterized by a large share of informality in the labor market. Informal labor contracts are usually defined as those not in accordance with regulations and unprotected regarding social security, although other definitions also consider the self-employed and workers of very small firms as informal workers. Informal jobs are often represented as disadvantaged positions because of the lack of protections and the precariousness of the labor conditions. However, there are reasons why workers would prefer the informal sector, such as greater flexibility and the opportunity to evade labor taxes and avoid inefficiencies that may accompany regulations (Maloney, 1999). In Brazil, the usual definition of the informal sector is the lack of a labor registry or "labor card", a requirement for formal salaried employees. The "labor card" guarantees that workers are protected by the law and their contracts follow the labor regulations such as the limit of weekly hours of work and minimum overtime pay and wage, among many others. Employers must contribute monthly to a fund (*Fundo de Garantia por Tempo de Serviço* - FGTS) and, upon dismissal, must pay severance linked to the worker's FGTS account, which increases with tenure. The benefit that workers get when they are fired can increase turnover rates, as employees may "force" their dismissal in order to receive the severance pay (Neri et al., 1997; Barros; Corseuil, 2004). Dismissed formal workers also have a right to unemployment insurance if they meet certain conditions, which impacts the unemployment exit rates. Partly due to a strict regulation, high firing costs and payroll taxes, the share of formal workers in Brazil is significant, although it differs across demographic groups and over the business cycle.

Search models can account for different employment states and provide insights on the flows across formality, informality and self-employment. Albrecht, Navarro e Vroman (2009) consider a model with productivity heterogeneity of workers in the formal sector and homogeneity in the informal sector. The opportunity cost of informality in this setting is heterogeneous: highly productive workers will turn down job offers from the informal sector and wait for formal jobs while workers with lower productivity are absorbed by the informal sector. Narita (2020) distinguishes three employment states: formal and informal employees and self-employed workers. Her framework accounts for life-cycle patterns of mobility between these states and assumes workers are heterogeneous in their ability to

be self-employed.

In Brazil, it is broadly consensual that turnover rates in the informal sector are higher than in the formal sector, which implies that employment spells in the formal sector are longer (Curi; Menezes-Filho, 2006; Hirata; Machado, 2010). Barros, Sedlacek e Varandas (1990) show that workers spend a relatively short period in informality. Neri et al. (1997) find evidences that informal workers have higher mobility and enter unemployment more frequently. At the same time, informal workers spend less time unemployed. The authors suggest that unemployment insurance and the FGTS severance pay would make formal workers incur in longer unemployment spells, while informal workers who do not receive such benefits are more likely to accept job offers, as they cannot afford unemployment.

Whenever the informal sector is significant in a country, a question that arises is whether the labor market is segmented, that is, whether similar individuals are paid higher wages in the formal sector compared to the informal sector. Besides wage differentials, labor market transitions can also characterize segmented labor markets as restrictions to worker's mobility into the formal sector are a manifestation of such segmentation. In a segmented labor market, formal jobs are limited and not all workers can be allocated in this sector. Those unable to find a formal job either search for one or, if they cannot afford to be unemployed, work informally until a better (formal) job is found. In this case, transition rates from the formal to the informal sector would be much lower than the other way around. Likewise, transitions from non-employment to the formal sector would be restricted to workers perceived as more highly productive. If the labor market is not segmented, informality is one of the many qualities of a job. Heterogeneous workers have different productivity levels in each sector and choose the sector in which wages are higher for them. Transitions from formality to informality and vice-versa would be symmetric, as well as transitions from non-employment into both sectors (Ulyssea, 2010).

In a comparative analysis of Argentina, Brazil and Mexico, Bosch e Maloney (2007) estimate transition rates based on continuous-time Markov processes. The authors argue that the reduced-form Markov model captures both barriers to mobility and the worker's disposition to flow based on their comparative advantage in each sector. They decompose the transition rates into a rate of separation and a propensity to move. A measure of revealed comparative advantage provides intuition on the effects of worker's characteristics and preferences over transition rates. Evidences suggest that while transition intensities between formality and informality are quite asymmetric, possibly suggesting a segmentation of the labor market, the calculated propensities (when the transition rates are adjusted for the turnover rate) and propensities adjusted for job openings (measuring comparative advantage), appear much more symmetric. The patterns are shared by all three countries, but the similarities are stronger between Brazil and Mexico, indicating little segmentation of the labor market in these countries.

The segmentation hypothesis may describe the labor market for different demographic groups. Cunningham e Salvagno (2011) find evidences that segmentation decreases with age, as the asymmetry of the flows between formality and informality weakens for older compared to younger workers in Brazil and Mexico. Evidences from flows of workers in Mexico suggest that the hypothesis might be adequate to describe the labor market for higher educated workers, while the lower educated would behave according to an integrated view (Gong; van Soest, 2002). Maloney (1999) stresses that workers access the formal sector with relative ease in Mexico but leave this sector at lower rates as the level of education increases. Gong, Soest e Villagomez (2004) point out that transition rates out of non-employment into formality are often lower than into informality for both sexes and education levels, indicating barriers to entry in the formal sector. Formal symmetry tests, however, demonstrate that the difference is not large enough to be significant except for low educated men.

It is clear that, in addition to variations in the stock variables and wage levels, transition rates are key to a more detailed description of the labor market. The rising availability of longitudinal data contributes to the empirical evaluation of labor market transitions. Panel surveys containing information on employment, income, participation and other socioeconomic characteristics allow researchers to follow individuals through time and investigate their labor market histories, even if just for a limited period of time. Individual characteristics are decisive to labor market outcomes, particularly age, gender and education. These features interact with the labor market structure and determine the observed patterns of wages, mobility and sector allocation.

3 A Continuous-time Markov Model

Markov chains are a simple structure for the analysis of transitions between labor market states as it describes a stochastic systems that "jumps" from one state to another according to a set of probabilities. Many studies consider discrete-time Markov models, in which individuals' labor market states are observed and compared in two periods a month, a quarter or a year apart. Transition probabilities are calculated taking the ratio of the number of individuals that completed a transition from state j to state k over a time interval T and the total number of individuals initially in state j. These probabilities are arranged in a transition matrix that governs the process. A major drawback of discrete-time descriptions of the labor market is that social processes are likely to be generated by an underlying continuous-time process (Singer; Spilerman, 1976). Discrete-time panel data often do not provide information on the precise time a transition occurs. Large national surveys usually follow an interviewing scheme characterized by equally spaced observations of individuals. The greater the time elapsed between two observations, the greater the possibility that more than one transition occur within the interval. As illustrated by Shimer (2012), an individual may be employed in the first interview but soon after lose their job. By the time of the second interview he/she may have already found another job and is thus classified again as employed. In this situation, two transitions would have been missed: one from employment to unemployment and another one from unemployment to employment. This has become known as time-aggregation bias.

A continuous-time framework has the advantage of providing estimates of the instantaneous rate of transition. The framework also yields the mean expected length of a spell in each state, which can be easily calculated from the transition intensities. Fougère e Kamionka (2008) present a summary of the use of continuous-time Markov chains to describe labor market mobility as well as estimation methods[2]. The methodology is described in the following sections.

3.1 Estimating Transition Intensities from Panel Data

Consider that individuals $i = 1, ..., N$ can transition between states that belong to a discrete finite state-space $\Omega = \{1, ..., K\}$. At each time $t \in \mathbb{R}^+$ an individual is in state $x(t) \in \Omega$ for a random period. He/She can move to a new state at any moment. Let $x(t)$ be a realization of the process $X(t)$. The probability of a particular realization is

$$Pr\Big[X(t) = x(t)|X(s_h) = x(s_h), X(s_{h-1}) = x(s_{h-1}), ..., X(s_0) = x(s_0)\Big] \qquad (3.1)$$

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[2] See also Jackson (2007).

for $0 \leq s_0 \leq s_1 \leq ... \leq s_{h-1} \leq s_h \leq t$ and $h \in \mathbb{N}$. Let $\mathcal{H}(s_h)$ represent the history of the process up to s_h. The probability in 3.1 can then be written as

$$Pr\Big[X(t) = x(t)|\mathcal{H}(s_h)\Big] \tag{3.2}$$

The Markovian assumption states that the probability of being in state $x(t)$ is independent from the history of the process. This memoryless property implies that only the current state of an individual determines the probability of being in each state in the future. Therefore

$$Pr\Big[X(t) = x(t)|\mathcal{H}(s_h)\Big] = Pr\Big[X(t) = x(t)|X(s_h) = x(s_h)\Big] \tag{3.3}$$

Let

$$p_{jk}(s,t) = Pr\Big[X(t) = k|X(s) = j\Big] \ \forall \ 0 \leq s \leq t, \ \forall \ j, k \in \Omega \tag{3.4}$$

be the probability that an individual will be in state k at a time t given that their state at a previous time s is j. A $K \times K$ matrix $P(s,t)$ with entries $[p_{jk}(s,t)]$ summarizes the transition probabilities between states over a time interval (s,t). The rows of $P(s,t)$ are such that $\sum_{m=1}^{K} p_{jm}(s,t) = 1$. The discrete time probability matrix is easily calculated from panel data, particularly if observations of individuals are equally spaced. An estimator of these probabilities is the ratio of the number of individuals that made the transition from j to k by the total number of individuals initially in state j. However, a transition from j to k may occur at any time in the interval (s, t), while panel surveys only provide information on the state of individuals at discrete times $(t_1, t_2, ..., t_{k_i})$. The limit of the transition probability as the time interval between observations goes to zero, called transition intensity, describes the *instantaneous* risk of moving between states. Formally, the transition intensity from state j to state k, $j \neq k$, is defined as:

$$\lambda_{jk}(t) = \lim_{\Delta t \to 0} \frac{Pr\Big[X(t + \Delta t) = k|X(t) = j\Big]}{\Delta t} \ \forall \ j, k \in \Omega, \ j \neq k \tag{3.5}$$

The $K \times K$ intensity matrix $\Lambda(t)$ associated to a continuous-time Markov process

$$\Lambda(t) = \begin{pmatrix} \lambda_{11}(t) & \lambda_{12}(t) & \cdots & \lambda_{1K}(t) \\ \lambda_{21}(t) & \lambda_{22}(t) & \cdots & \lambda_{2K}(t) \\ \vdots & \vdots & \ddots & \vdots \\ \lambda_{K1}(t) & \lambda_{K2}(t) & \cdots & \lambda_{KK}(t) \end{pmatrix} \tag{3.6}$$

satisfy

$$\lambda_{jk}(t) = \begin{cases} \lambda_{jk}(t) \in \mathbb{R}^+, \ \text{if } j \neq k \text{ for } j, k \in \Omega \\ -\sum_{j \neq k} \lambda_{jk}(t) \leq 0, \ \text{if } j = k \text{ for } j \in \Omega \end{cases} \tag{3.7}$$

If the Markov process is time-homogeneous, the transition intensities are also independent of t, thus $\lambda_{jk}(t) = \lambda_{jk} \; \forall t$. Moreover, time-homogeneity implies that the transition probabilities are a function of $(t - s)$ only, that is, $P(s,t) = P(0, t - s) \equiv P(t - s)$ $\forall t > s$. Consider a time interval $(t - s) = T, \; T \in \mathbb{R}^+$. The Kolmogorov forward equations

$$\frac{d}{dT}P(T) = P(T)\Lambda \tag{3.8}$$

have a unique solution given by

$$P(T) = exp[\Lambda T] \tag{3.9}$$

given the initial condition P(0) = I (Cox; Miller, 1977).

Transition intensities between j and k can be adjusted for the turnover rate in state j by calculating the ratio

$$r_{jk} = \frac{-\lambda_{jk}}{\lambda_{jj}} \tag{3.10}$$

Bosch e Maloney (2007) call r_{jk} the "propensity" to move from state j to state k, the transition rate conditional on the state j's overall turnover rate. The authors argue that the propensity measure is convenient when comparing the flows of different demographic groups because if the individuals of a group A transition from state j to state k more intensely than those of group B, it may be simply because individuals of group A transition from state j into any other state more intensely, that is, the overall turnover of state j for group A is higher.

Another property of time-homogeneous Markov models is that the sojourn time in state $j \in \Omega$ is exponentially distributed with parameter λ_{jj}. It implies that the average duration of a spell in state j equals $-1/\lambda_{jj}$, the inverse of the turnover rate in state j.

3.2   Maximum Likelihood Estimator

Kalbfleisch e Lawless (1985) propose a method to obtain maximum likelihood estimates of the transition intensities in time-homogeneous Markov models. The authors consider panel data, in which data is reported in a series of discrete-time observations of the states. Observation times are assumed to be non-informative.

Let t_r and t_{r+1} be two consecutive observation times of the states of an individual i. The contribution to the likelihood from a pair of states $(x_i(t_r), x_i(t_{r+1}))$ is

$$L_{i,r} = p_{x_i(t_r)x_i(t_{r+1})}(t_{r+1} - t_r) \tag{3.11}$$

the $(x(t_r), x(t_{r+1}))$ entry of individual i's probability transition matrix $P_i(t)$ evaluated at $t = t_{r+1} - t_r$. Each individual's contribution is the product of the contribution of each pair

of states, $\prod_r L_{i,r}$. The total likelihood is the product of all individual contributions:

$$L(P(t)) = \prod_{i,r} L_{i,r}(P_i(t)) = \prod_{i,r} p_{x_i(t_r)x_i(t_{r+1})}(t_{r+1} - t_r) \qquad (3.12)$$

From equation (3.9), the likelihood can be written as a function of the transition intensities, so that $L(\Lambda)$ is maximized in terms of the transition rates λ. Initial values for the transitions are required in order to employ numerical methods to maximize the likelihood. Considering that n_j is the number of individuals initially in state j and n_{jk} those who transitioned from j to k exactly at the observation time, then $\lambda_{jk}/\lambda_{jj}$ can be approximated by n_{jk}/n_j. The mean sojourn time $1/\lambda_{jj}$ can be estimated by S_j/n_j, where S_j is the time spent in state j. For each transition jk, a crude estimate of λ_{jk} is therefore n_{jk}/S_j (Jackson, 2007). In the present study, the BFGS[3] optimization algorithm was used to search for the minimum of minus the log of equation (3.12). From the Hessian at the optimum, the standard errors were extracted for each transition intensity.

3.3 Covariates

In order to consider the transition intensities as a function of a covariate vector $\mathbf{z}(t)$, Marshall e Jones (1995) propose a proportional hazards model, describing the intensities as

$$\lambda_{jk}(\mathbf{z}(t)) = \lambda_{jk}^0 exp\Big[\beta_{jk}'\mathbf{z}(t)\Big] \qquad (3.13)$$

where λ_{jk}^0 is the baseline transition intensity between states j and k and β_{jk}' is the vector of log-linear effects of the covariates on this baseline intensity. A negative log-linear effect is translated into a multiplicative factor $exp[\beta_{jk}'\mathbf{z}(t)]$ between zero and one, shrinking the baseline transition rate, while a positive effect expands the transition rate by a factor that is greater than one. These factors, called hazard ratios for each covariate, indicate the effect of the explanatory variables and are different for each transition of the matrix. This specification does not allow for unobserved heterogeneity, although it can be incorporated and potentially improve the fit of the model (Van den Berg; Ridder, 1998).

Transition probabilities are now a function of the covariates and the likelihood function becomes

$$L(P(t; \mathbf{z}(t))) = \prod_{i,r} p_{x_i(t_r)x_i(t_{r+1})}(t_{r+1} - t_r; \mathbf{z}(t)) \qquad (3.14)$$

It is assumed that the value of each covariate is constant between two consecutive observations. Equation (3.14) is then maximized with respect to both λ and β.

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[3] Broyden–Fletcher–Goldfarb–Shanno method for iteration on nonlinear optimization problems.

4 An application to Brazil

4.1 Data and Summary Statistics

The survey *Pesquisa Nacional por Amostra de Domicílios Contínua* (PNADC) provides the longitudinal data used to analyze the Brazilian labor market. The quarterly microdata, covering all national territory, presents indicators of labor market conditions and other socioeconomic characteristics. Individuals in the sample are interviewed every quarter for five consecutive quarters, which provides five (or less, due to attrition) equally spaced observations of their labor market states. I only consider individuals who have at least two observed states, otherwise a transition cannot be computed. The data covers the period from the first quarter of 2017 to the first quarter of 2019 and consists of individuals aged 21 to 65 living in urban areas (see Appendix A for more detail on the dataset).

A five-state model is assumed to describe the Brazilian labor market. Employed individuals are classified as self-employed (SE), informal salaried workers (I) or formal salaried workers (F). Formality is defined as those labor contracts that conform to labor protections and social security: formal workers have a "labor card", while informal workers do not. The category of self-employment does not distinguish workers as formal or informal. The two categories of non-employment are unemployment (U) and inactivity (N). The discrete state space is therefore $\Omega = \{SE, I, F, U, N\}$. Bosch e Maloney (2007) and Curi e Menezes-Filho (2006) use a similar definition of labor market states in their studies. Other authors consider different definitions of informality. Hirata e Machado (2010) separate domestic workers, salaried workers without a "labor card", formal workers (salaried workers with a "labor card", autonomous professionals and employers with six to ten employees) and informal workers (self-employed workers and employers with up to five employees). Their definition of informality is not related to the compliance to the labor legislation, but to the firm size and the precariousness of the position. In this study, I choose not to consider employers of either big or small firms and to combine the self-employed into a single category.

Observed paths of labor market states are assumed to be generated by a time-homogeneous Markov model with transition intensity matrix

$$\Lambda = \begin{pmatrix} \lambda_{SE,SE} & \lambda_{SE,I} & \lambda_{SE,F} & \lambda_{SE,U} & \lambda_{SE,N} \\ \lambda_{I,SE} & \lambda_{I,I} & \lambda_{I,F} & \lambda_{I,U} & \lambda_{I,N} \\ \lambda_{F,SE} & \lambda_{F,I} & \lambda_{F,F} & \lambda_{F,U} & \lambda_{F,N} \\ \lambda_{U,SE} & \lambda_{U,I} & \lambda_{U,F} & \lambda_{U,U} & \lambda_{U,N} \\ \lambda_{N,SE} & \lambda_{N,I} & \lambda_{N,F} & \lambda_{N,U} & \lambda_{N,N} \end{pmatrix} \tag{4.1}$$

As in Fougère e Kamionka (1992), the estimation of the transition intensities was carried out separately for different age and gender groups. The ten subsamples are of males and females aged 21-29, 30-39, 40-49, 50-59 and 60-65 years old. This stratification is a way to consider the heterogeneity of labor market mobility patterns across demographic groups. I assume that, within each subsample, individual labor market state paths are governed by the same transition matrix, but the matrices differ across subsamples. Bosch e Maloney (2007) splits the sample by age groups and also by low and high education, recognizing that individuals with different educational levels may be governed by distinct transition matrices too. The present study extends the work of Fougère e Kamionka (1992) by introducing education covariates in order to estimate their influence on labor market transitions. Differently from Bosch e Maloney (2007), who split the sample into educational groups and estimate the transition intensity matrices for each group, education is here introduced as a vector of explanatory variables whose effects on the transition rates are jointly estimated as described in the previous section. Two dummies of education levels are considered: the High School dummy equals one if the individual has completed at least High School or equivalent education, and zero otherwise; the College dummy equals one for individuals who completed at least a bachelor degree, and zero otherwise. It is assumed that the education level is fixed between two observations of the labor market state.

Tables 1, 2 and 3 provide summary statistics of the stocks of workers over the two-year period sample considered for this study. Table 1 presents the distribution of individuals according to their level of education. We can see that the shares of women with both High School and College exceed the shares of men with these degrees. The prevalence of individuals with less than High School is also higher among older workers; it increases monotonically with age for both men and women. This pattern indicates improvements in the educational attainment in Brazil as younger cohorts are more likely to have completed at least High School (although it says nothing about the quality of education).

Table 2 displays the distribution of employed individuals across the three employment states. The shares of males and females employed in the formal sector are very similar up until the age 40-49. For older workers, the share of males employed formally exceeds the correspondent share of females. The incidence of self-employment is higher for males and increases with age for both males and females. The fraction of employed workers in the informal sector, on the other hand, is higher for females and while it increases as women age, the opposite happens to men: 23 percent of both male and female workers aged 21-29 are employed in the informal sector, but the share of women aged over 40 employed in this sector is twice as high as the share of men.

Table 1 – Education levels per subsample (%)

	Males				
	21-29	30-39	40-49	50-59	60-65
Less than High School	36.1	42.4	58.2	65.7	69.3
High School Diploma	55.0	43.9	32.0	25.8	20.6
College Degree	9.0	13.8	9.8	8.5	10.2
	Females				
	21-29	30-39	40-49	50-59	60-65
Less than High School	26.0	34.2	51.3	62.4	68.0
High School Diploma	59.7	46.5	36.1	26.5	20.0
College Degree	14.4	19.4	12.6	11.2	12.1

Note: Author's calculations based on subsamples of Panel 6 from the PNADC dataset. The data collection period is from the first quarter of 2017 to the first quarter of 2019. Sampling weights were not considered.

For men and women, the fraction of workers employed in the formal sector decreases with age while the share in the self-employment sector increase. Twenty percent of male workers aged 21-29 are self-employed; the fraction reaches almost 60 percent for those aged 60-65. The pattern is similar for females. This is compatible with the idea of barriers to entry into self-employment for younger workers who have not yet accumulated much capital. The large share of young men and women employed informally is also is accordance with Bosch e Maloney (2007) and Cunningham e Salvagno (2011), who suggest that the youth may use informal jobs as a "stepping stone" to acquire experience and skills before transitioning to a formal position. Individuals become less likely to be employed formally as they age, yet males seem much more likely to relocate to self-employment than to informal salaried jobs. Women, on the other hand, have an increasing participation both in the self-employment and the informal sector.

Considering the different education levels, the patterns of increasing fractions of self-employment and decreasing fractions of formality as workers age persist for men and women (see Table 9 of Appendix B). Among female workers of all ages, those with less than High School are the most likely to be informally employed compared those of the other education levels and compared to males of the same education level. Females with higher education display shares of informality much lower, suggesting that educational attainment may have a greater impact on females' sector allocation compared to males.

Table 2 – Distribution of employed workers across sectors per subsample (%)

	21-29	30-39	40-49	50-59	60-65
			Males		
Self-Employed	20.2	30.4	39.6	48.6	57.5
Informal Salaried	23.0	14.5	12.7	11.9	13.9
Formal Salaried	56.8	55.0	47.8	39.5	28.6
			Females		
	21-29	30-39	40-49	50-59	60-65
Self-Employed	17.2	23.9	28.1	36.2	48.9
Informal Salaried	23.5	20.8	24.4	26.2	27.4
Formal Salaried	59.3	55.4	47.5	37.6	23.7

Note: Author's calculations based on subsamples of Panel 6 from the PNADC dataset. The data collection period is from the first quarter of 2017 to the first quarter of 2019. Sampling weights were not considered.

Table 3 displays two of the most important labor market indicators: the unemployment and the labor force participation rates calculated for the subsamples, considering the education level. Women of all ages participate less in the labor market, especially the lower educated. This pattern indicates that the opportunity cost of inactivity may be lower for females. As they are often expected to be the primary caregivers within a household, it is not unusual that women are found to have a weaker attachment to the labor force. The educational level is also an important determinant of the participation decision. The difference in the participation rate of College educated men and those who did not complete High School reaches up to 10 percentage points at the age 40-49. For women, the gap is even wider: over 30 p.p. for the 21-29 age group and over 20 p.p. for the 30-39 and 40-49 groups. This difference in the participation gap between education levels suggest that the influence of education on the participation decision may be higher for women, as they are much more likely to participate if they have a College degree. In fact, young females with a College degree participate almost as much as their male counterparts, but the gap starts to widen as they get older.

The high unemployment rates across all demographic groups illustrate that, two years later, the Brazilian economy was still struggling to recover from the 2014-2016 economic crisis. Workers 21-29 years old display the highest rates: one every four young women and almost one every five young men were not working but actively searching for work in the 2017-2019 period considered. As the level of education increases, the unemployment rate falls, leaving low educated women with the highest unemployment rate across all groups: 32 percent. The unemployment rate of males decreases with education for all age groups; the difference between the unemployment rate of males with less than High School and those with a College degree reaches up to four percentage points at early

ages and persist until the last age group, although it drops to 2 p.p. for those 50-59 years old and less than 1 p.p. for those 60-65. For females, on the other hand, education seems to play an important role only for younger workers. For those over 40 years old, the difference in the unemployment rate between the lowest and the highest educated is small and for those 60-65 the unemployment rate even increases with education.

Table 3 – Participation and Unemployment Rates per subsample (%)

	Participation Rates				
	Males				
	21-29	30-39	40-49	50-59	60-65
Total	83.4	91.3	88.1	74.3	48.0
Less than High School	82.8	87.1	84.8	73.3	47.5
High School Diploma	83.0	94.2	92.4	76.0	49.2
College Degree	88.3	95.2	94.1	77.1	48.8
	Females				
	21-29	30-39	40-49	50-59	60-65
Total	66.6	70.4	65.1	44.8	20.8
Less than High School	52.1	59.6	58.0	41.0	19.5
High School Diploma	68.6	73.1	69.6	51.6	24.9
College Degree	84.1	83.4	80.7	49.9	21.9
	Unemployment Rates				
	Males				
	21-29	30-39	40-49	50-59	60-65
Total	18.6	9.9	8.7	8.8	7.8
Less than High School	19.7	11.3	9.5	9.3	8.0
High School Diploma	18.5	9.5	8.2	8.4	7.6
College Degree	15.3	7.2	6.0	7.2	7.4
	Females				
	21-29	30-39	40-49	50-59	60-65
Total	25.2	15.3	11.8	8.8	5.4
Less than High School	32.0	17.6	11.8	8.4	4.9
High School Diploma	25.1	15.6	11.6	9.4	5.9
College Degree	18.1	12.0	12.4	9.1	6.8

Note: Author's calculations based on subsamples of Panel 6 from the PNADC dataset. The data collection period is from the first quarter of 2017 to the first quarter of 2019. Sampling weights were not considered.

4.2 Transitions and the Effect of Education

The `msm` package available in R provides an implementation of the continuous-time Markov model described in Section 3. The package was used to estimate the transition intensity matrices and the hazard ratios associated to the education dummies. For more detail on the package's characteristics and usage, see Jackson (2007). The estimates of each transition rate for each subsample are presented in Tables 10, 11 and 12 in Appendix B. Covariates are set to their means so that the values represent an average transition intensity. Flow rates for particular education groups within a subsample are computed by setting the College and High School dummies accordingly.

Table 4 presents the observed and expected relative stocks of workers in each of the five states by the fifth observation point, that is, the observed and expected probabilities of being in each state by the fifth interview. The model's predictions are close to the observed values of the state probabilities, which indicates that the model is able to fairly reproduce the patterns observed in the data. Deviations are rarely larger than one percentage point. The largest differences are found in the group of 60-65 year-old males, for whom the model predicts that 54.9 percent of individuals would be inactive, while the observed value is 52.9 percent. The expected shares of formality, informality and self employment fall behind the observed shares for this group.

Table 4 – Observed and Expected percentages of workers in each state (%)

	Males									
	Self-employment		Informal		Formal		Unemployment		Inactivity	
Age	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
21-29	13.8	14.0	15.3	15.3	38.4	39.5	15.7	15.1	16.7	16.2
30-39	25.0	25.8	11.9	11.7	45.4	44.8	8.9	9.1	8.8	8.6
40-49	31.9	32.7	10.2	9.9	38.6	38.0	7.3	7.6	12.0	11.9
50-59	32.8	32.8	7.9	7.9	27.1	25.9	6.3	6.4	25.9	27.0
60-65	25.2	24.5	5.9	5.7	12.4	11.4	3.6	3.6	52.9	54.9
	Females									
	Self-employment		Informal		Formal		Unemployment		Inactivity	
Age	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
21-29	8.7	9.0	11.7	11.7	29.4	30.1	16.9	16.8	33.4	32.4
30-39	14.4	14.9	12.2	12.2	33.2	32.5	10.6	10.9	29.6	29.5
40-49	16.3	16.8	14.1	13.8	27.3	26.7	7.8	7.7	34.4	35.0
50-59	14.8	14.8	10.8	10.5	15.3	14.4	3.9	3.9	55.1	56.5
60-65	9.7	9.6	5.4	5.2	4.6	4.0	1.1	1.1	79.2	80.2

Note: the expected and observed relative stocks of workers in each state in the other four interviews is similar and therefore not reported.

4.2.1 Flows out of the Labor Force

Figure 1 displays the flow rates out of the labor force from all three employment states and from unemployment. It is clear that most transitions are greatly influenced by age and gender. As expected, transitions out of the labor force from all states of activity are U-shaped with respect to age: compared to the middle-age groups (30-39 and 40-49), younger and older workers are more likely to flow into inactivity, the latter flowing more intensely than the former. This pattern evidences the life-cycle elements of the transition intensities into inactivity. Young workers who are entering the labor force may initially experience higher mobility between (temporary) employment and full-time schooling because the costs of returning to school are compensated by the benefits reflected in pecuniary and non-pecuniary prospects in the labor market. The flows out of the labor force among the young is unlikely to be permanent, the opposite being true for the group of older workers, who usually transition into inactivity due to retirement.

Figure 1 – Transition Intensities out of the Labor Force
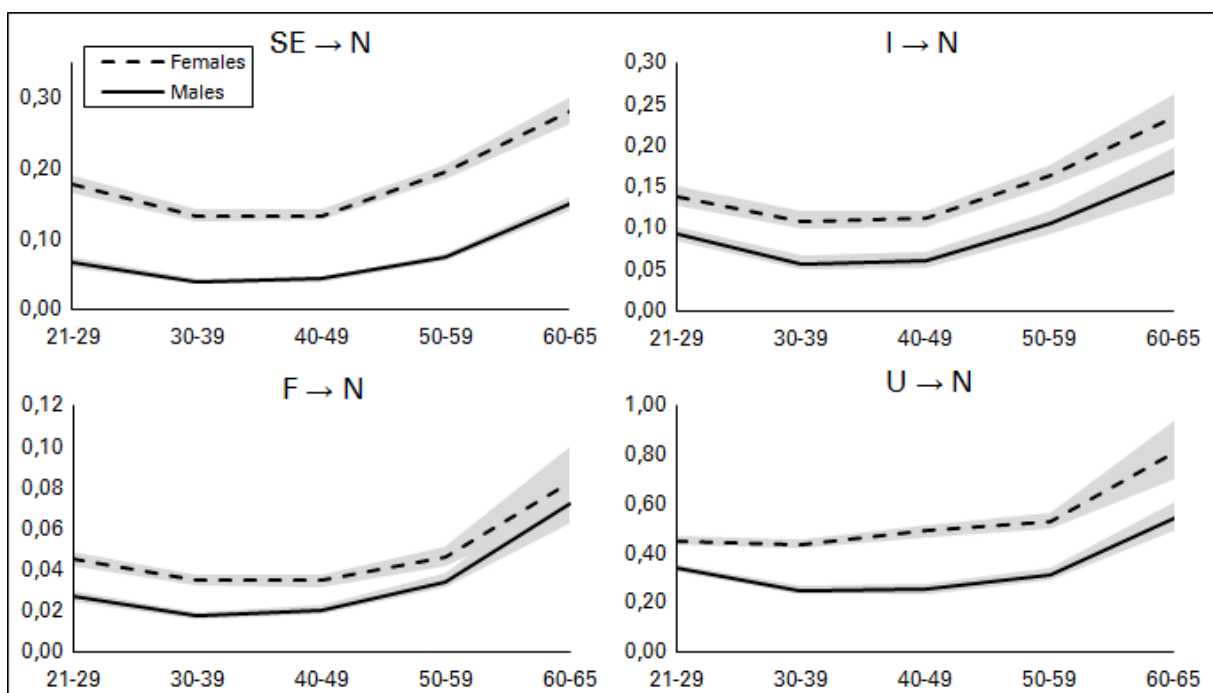
Note: Author's estimations results. Confidence intervals at the 95% level.

Females transition into inactivity more intensely than males. This behavior is compatible with existing gender roles according to which women are the primary caregivers for children and the elder, and thus more likely to quit their jobs (or be dismissed) in order to fulfill this role. The difference between males and females is more pronounced for workers who departure from self-employment: females are two to three times more likely to flow from self-employment to inactivity than males. Flows from informality are also up to two times more intense for females while the transition intensity from formality into

inactivity is very similar for both genders. Adjusting for the turnover rate in the departure state, the propensities to flow into inactivity are also higher for females (Figure 2).

Figure 2 – Propensities to flow into Inactivity from Employment
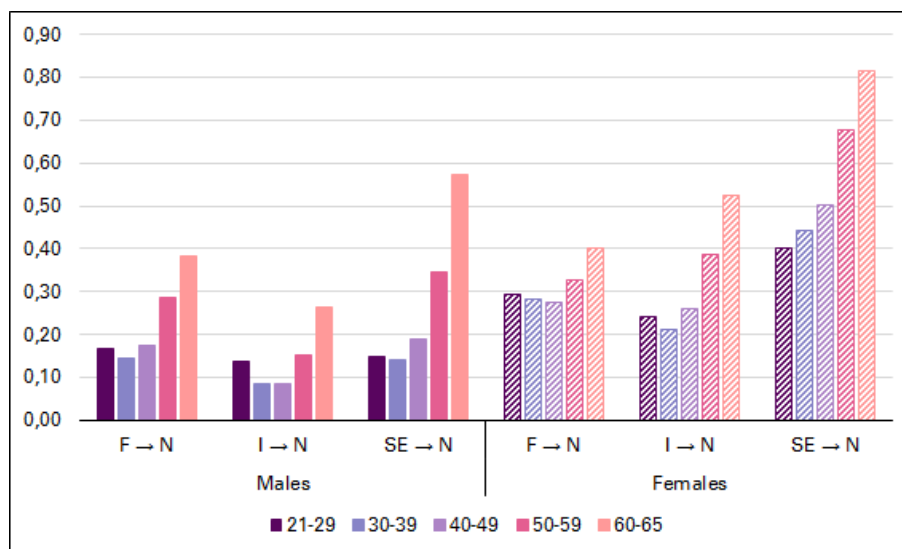
Note: Author's estimations results.

Transition intensities from the formal sector into inactivity are relatively low compared to the flows from self-employment and informality for most age and gender groups. Males transition from self-employment almost as intensely as from informality into inactivity and half as intensely when the departure state is formality. After adjusting for the turnover rate, however, the pattern changes. For males of all age groups except 21-29 (for whom the propensities to flow out of the labor force are nearly equal for all three employment departure states), the propensity to flow from informality into inactivity is lower than from formality and self-employment.

The transition intensities from unemployment into inactivity are higher than from all three employment states for all demographic groups. This is partly because the turnover rate in the unemployment state is very high, therefore individuals flow out of this state into all four other states very intensely. In line with the argument of Pries e Rogerson (2009), women are more likely to flow from unemployment to inactivity, possibly discouraged with respect to their labor market prospects compared to the costs to search for a job. Compared to males, they transition 33 to 93 percent more intensely from unemployment to out of the labor force, depending on the age group.

The education level is expected to lower transitions into inactivity. The most qualified workers perceive inactivity as too costly compared to the investments they made in order to complete their degrees, and compared to the wage they could earn if they were employed. The estimates in Figures 3 and 4 corroborate this logic. The four panels of Figure 3 display the hazard ratios corresponding to the College degree's effect on each transition intensity out of the labor force for each demographic group. From all three

employment states, a College degree is associated with a lower flow out of the labor force, and most coefficients are significant (the confidence interval for the hazard ratio does not encompass the number one). Workers with higher education flow into inactivity from formality and informality roughly half as intensely as their lower educated counterparts. The reduction is even greater if the departure state is self-employment. The effect of a High School diploma is not as sizable, yet it also decreases the transition intensities into inactivity from all three employment states and from unemployment (Figure 4). Women with less than High School are the most likely to flow out of the labor force. The transition intensities into inactivity for females with a College degree, however, are very similar to the intensities of males, particularly during their young and prime-age years. Royalty (1998) and Theodossiou e Zangelidis (2009) find comparable results, suggesting that highly educated females behave similarly to males in their transitions out of the labor force.

A College degree has a positive and significant effect on the transition from unemployment to inactivity for men aged 30-39. Apart from this unanticipated positive value, the hazard ratios of College are non-significant for the other age groups of males. For females, the effect of a higher education degree on this transition is negative for all age groups, although not significant for the 60-65 group. A High School diploma has a similar effect. These results suggest that education increases women's attachment to the labor force, as they are less likely to quit searching for a job, while men's unemployment to inactivity transition is mostly unaffected by their educational attainment.

4.2.2 Flows in and out of Unemployment

Figure 5 shows the transition intensities from unemployment into each one of the three employment states. Males of all age groups flow out of unemployment more intensely than females, particularly if the arrival state is self-employment. Curi e Menezes-Filho (2006)'s study had already detected that the probability to transition out of unemployment into all three employment states, compared to the alternative of remaining unemployed, increases if the individual is male. Flow rates from unemployment into formality are decreasing with age for both men and women, suggesting that it becomes harder to find a formal job as workers get older. Transitions into informality, however, differ: while males display a decreasing flow rate from unemployment to informality as they age, the opposite happens with females, who increasingly flow into informality as they grow older. This difference in transition rates reflects on the increasing share of women and decreasing share of men informally employed (Table 2). The pattern is similar when the intensities are adjusted for the turnover rate (Figure 6). Both intensities and propensities to flow into formality are lower for men and women of all ages when compared to the transitions into informality. This may result from barriers to entry into the formal sector, which could indicate a segmentation of the labor market.

Figure 3 – Hazard Ratios of College - Transitions out of the Labor Force
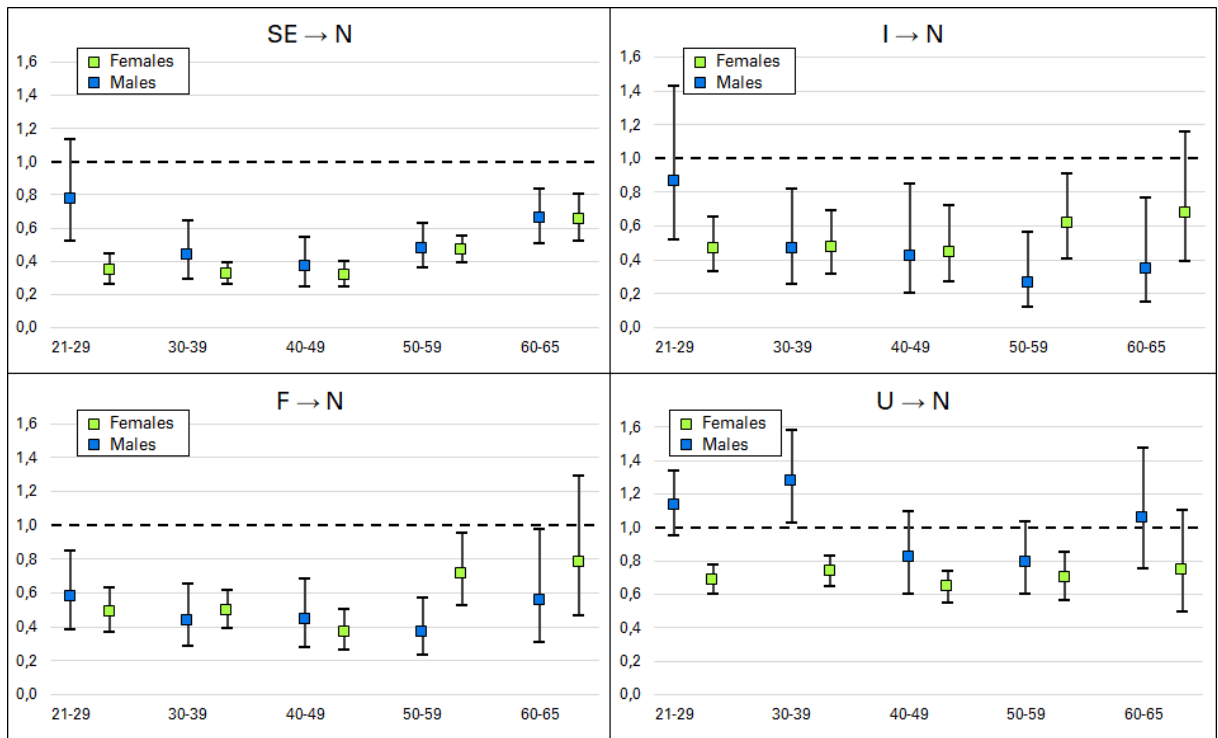
Note: Author's estimations results. Confidence intervals at the 95% level assuming normality of the log-effect. Hazard ratios calculated exponentiating the estimated effect of the covariate on the log-transition intensity. A HR above (below) 1 (dashed line) means that the effect of the covariate is positive (negative). Confidence intervals that encompass the number 1 imply that the covariate is not significant.

Figure 4 – Hazard Ratios of High School - Transitions out of the Labor Force
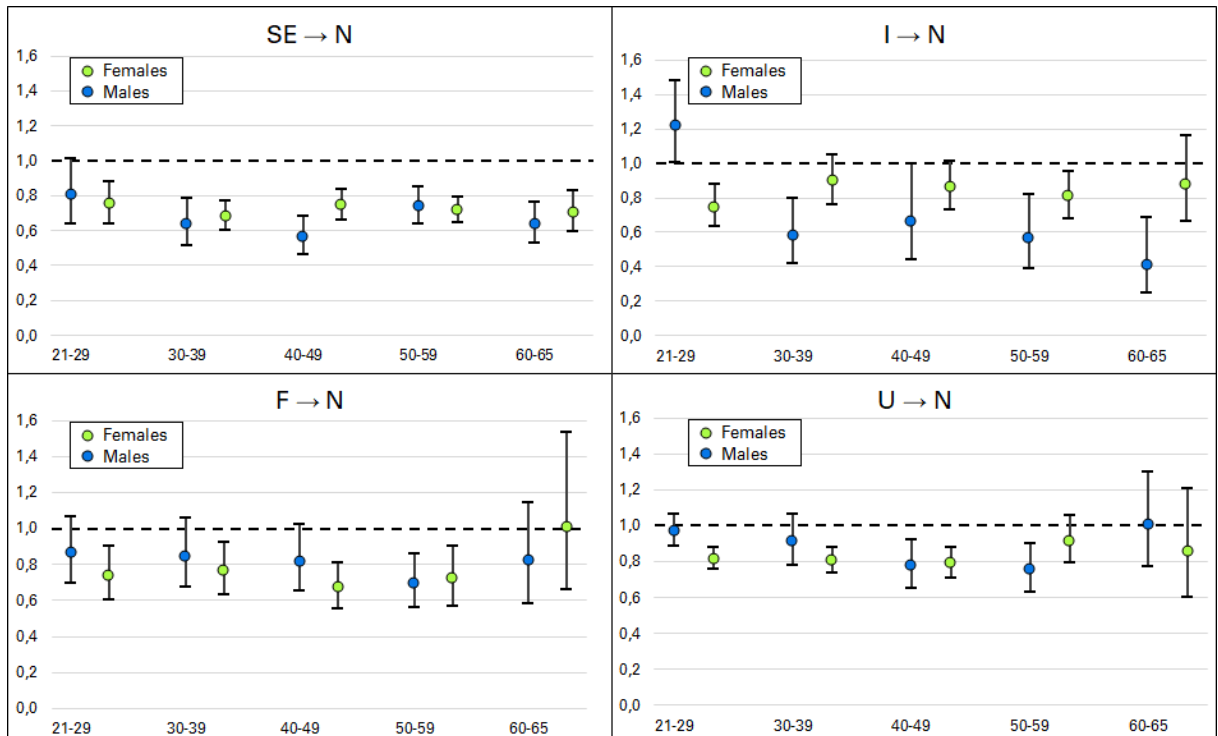
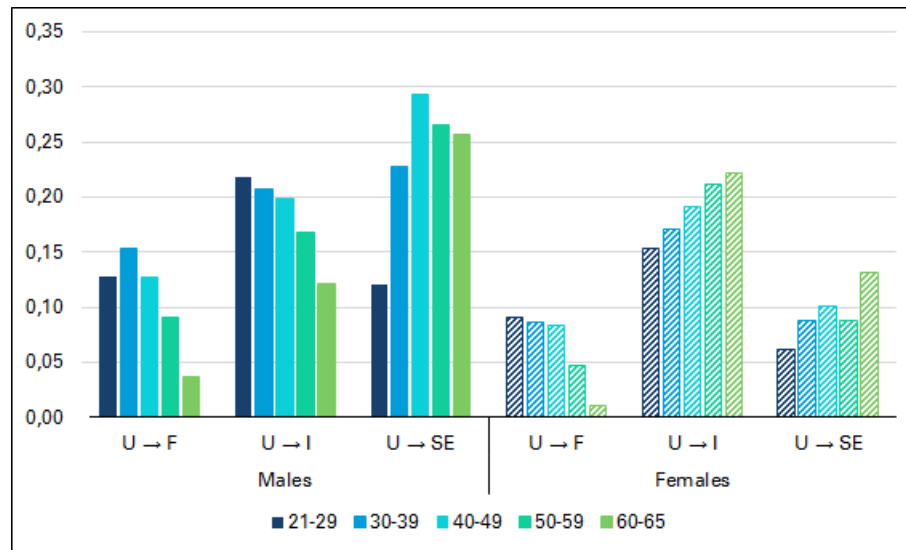Note: Author's estimations results. Confidence intervals at the 95% level assuming normality of the log-effect. Hazard ratios calculated exponentiating the estimated effect of the covariate on the log-transition intensity. A HR above (below) 1 (dashed line) means that the effect of the covariate is positive (negative). Confidence intervals that encompass the number 1 imply that the covariate is not significant.

Figure 5 – Transition Intensities out of Unemployment

Figure 6 – Propensities to flow out of Unemployment
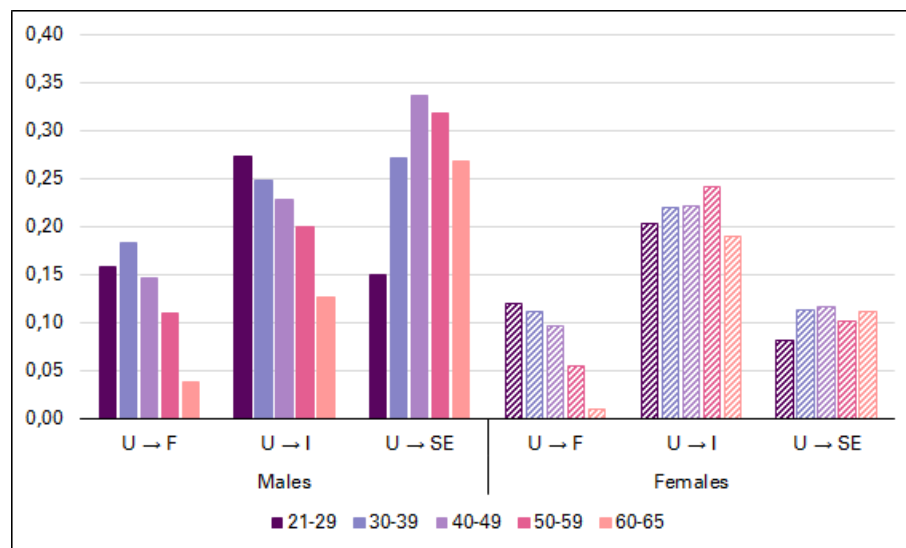
The cycle proposed by Cunningham e Salvagno (2011), according to which young workers move into informality for a "stepping stone" job before moving to a formal position and later into self-employment seems adequate to describe the behavior of Brazilian males: they flow from unemployment into informality more intensely than to the other categories of employment when they are young. As they age, males flow more intensely from unemployment into self-employment compared to the other employment states. The pattern is the same if we analyze the flows from inactivity straight into each employment state. Informality, rather than self-employment or formality, seems more likely to be a port of entry into work for young males in Brazil. Maloney (1999), Bosch e Maloney (2007) and Cunningham e Salvagno (2011) reach similar conclusions for other Latin American countries. Females transition more intensely from unemployment to informality when they

are young, as do males, indicating that this sector is likely to be the port of entry for women too. However, older women do not flow into self-employment more intensely than into informality, as do older men. The intensity and propensity to flow from unemployment into informality is higher for females at all ages, compared to the other employment sectors.

The relationship between education and the transitions out of unemployment can be ambiguous. On the one hand, highly educated workers may have an increased job offer arrival rate that yields more opportunities to choose from, which could reduce the length of the search process. At the same time, because their reservation wage is higher they can be "pickier" in their job search, which decreases the transition rate out of unemployment and increases their unemployment spell. The less qualified workers are sometimes in a position where they cannot afford to be unemployed for too long so that they are more willing to accept an offer that a qualified worker wouldn't. Table 5 shows the average expected unemployment spell implied by the Markov model. For males and females of all ages there is a positive correlation between education and the mean sojourn time in the unemployment state. While individuals with less than High School spend on average three months searching for work, the most qualified workers spend four to six months. Bosch e Maloney (2007) find a similar correlation in Brazil, Mexico and Argentina.

Besides the higher reservation wage and other requirements that can restrict the set of acceptable job offers for more qualified workers, another possible explanation for this correlation is the fact that individuals with a High School diploma and a College degree participate more in the formal sector and are therefore entitled to unemployment insurance when they are dismissed. In Brazil, workers receive three to five monthly unemployment insurance payments, depending on the worker's tenure in the last job and how many times he or she has requested the benefit. Neri et al. (1997) and other authors had already noted that the Brazilian regulation of formal employment contracts could lead to an increased unemployment duration. As such contracts are more frequent among the most qualified workers, it could partially explain their longer unemployment spell. From the reduced form estimates of the transition rates, however, it is not possible to disentangle the factors that lead to an increased unemployment spell for the highly educated, whether it is associated with the preferences of picky workers or the effect of regulation, or both. A finer analysis of this relationship would be required in order to establish causality.

Table 5 – Mean Sojourn Time in Unemployment by education level,
age and gender

	Males				
	21-29	30-39	40-49	50-59	60-65
Less than High School	1.1	1.0	1.0	1.0	1.0
	(0.0223)	(0.0234)	(0.0238)	(0.0262)	(0.0440)
High School Diploma	1.3	1.3	1.3	1.4	1.2
	(0.0236)	(0.0341)	(0.0461)	(0.0650)	(0.1071)
College Degree	1.3	1.5	1.4	2.0	1.2
	(0.0668)	(0.0867)	(0.1072)	(0.1892)	(0.1611)
	Females				
	21-29	30-39	40-49	50-59	60-65
Less than High School	1.2	1.1	1.0	1.0	0.8
	(0.0275)	(0.0259)	(0.0244)	(0.0327)	(0.0588)
High School Diploma	1.4	1.3	1.3	1.3	0.9
	(0.0214)	(0.0282)	(0.0367)	(0.0546)	(0.1096)
College Degree	1.4	1.5	1.6	1.5	1.1
	(0.0692)	(0.0538)	(0.0800)	(0.1089)	(0.1793)

Note: Average number of quarters an individual is expected to spend in unemployment
before transitioning into any of the four other states. Standard Errors in parenthesis.

The education level impacts differently the flows out of unemployment into formality and informality. If informal jobs are more precarious and pay lower wages, the most qualified workers will avoid this sector and flow into formality more intensely than into informality. Figure 7 shows the hazard ratios of High School (left panels) and College (right panels) associated to the transition intensities from unemployment into the informal and formal sectors. Both High School and College have a decreasing effect on transitions from unemployment into informality (upper panels). A High School diploma roughly halves this flow rate for males and females. The effect of a College degree is even more pronounced, except for 21-29 years old females, for whom the negative effect is the smallest, although still significant. These results are in line with Maloney (1999), whose study suggest that informality is a port of entry into employment particularly important, yet not exclusive, for lower educated young workers.

The effect of education on the transition from unemployment to formality is the opposite (lower panels of Figure 7). A High School diploma significantly increases the rate at which males and females aged 21-29 and 30-39 and males aged 40-49 transition into formal positions. These groups of workers transition into formality 30 to 80 percent more intensely than their counterparts with less than High School who face greater difficulties to find a formal job. The hazard ratio of High School is non-significant for older workers. The College degree has an interesting effect on transitions into formality: it only increases

significantly the unemployment exit rate into formality of young females, for whom a higher education can double this flow rate. The effect of College is mostly insignificant for males and is even negative for men aged 50-59.

Figure 7 – Hazard Ratios of High School and College - Transitions from Unemployment to Formality and Informality
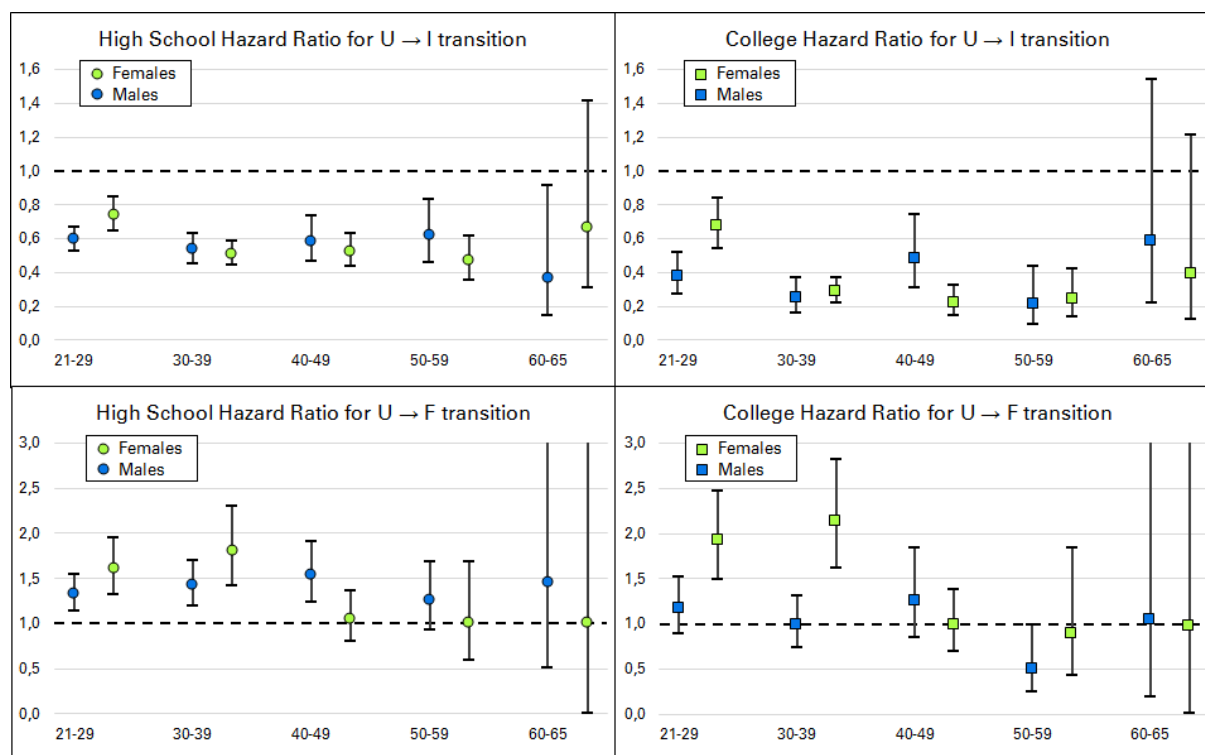
 Note: Confidence intervals at the 95% level assuming normality of the log-effect. Hazard ratios calculated exponentiating the estimated effect of the covariate on the log-transition intensity. Some upper limits of the confidence intervals of non-significant hazard ratios were omitted to allow a better visualization of the estimates.

Although the transition intensities from unemployment into the informal sector exceeds the flows into the formal sector, it seems like a higher education prevents unemployed workers from entering informality more than it improves their chances of transitioning into formality, the exception being young females who are significantly more likely to transition into formality when they are more qualified. The fact that the educational attainment is associated with higher flows from unemployment to formality for the young while for older workers the effect is less significant can also indicate that for older workers other factors influence this transition. Young workers that are transitioning into the workforce sometimes only have their formal education to signal their productivity and therefore this variable is more important for this group. Older workers, on the other hand, can signal their productivity with experience and other achievements in the labor market, as well as formal education.

The reverse flow rates (from employment to unemployment) are presented in Figures 8 and 9. The transitions into unemployment from all three employment states

decreases with age for males and females. Regardless of age or gender, separation rates from informality into unemployment are much greater than those from formality into unemployment (Figure 8). This is in part due to the high turnover in the informal sector, which makes workers more likely to leave informality into any other state. In fact, when I adjust for the turnover rate (Figure 9), these disparities are attenuated and sometimes even reversed: the propensity to flow into unemployment for young males and females is higher when the departure state is formality compared to informality and self-employment.

Figure 8 – Transition Intensities into Unemployment
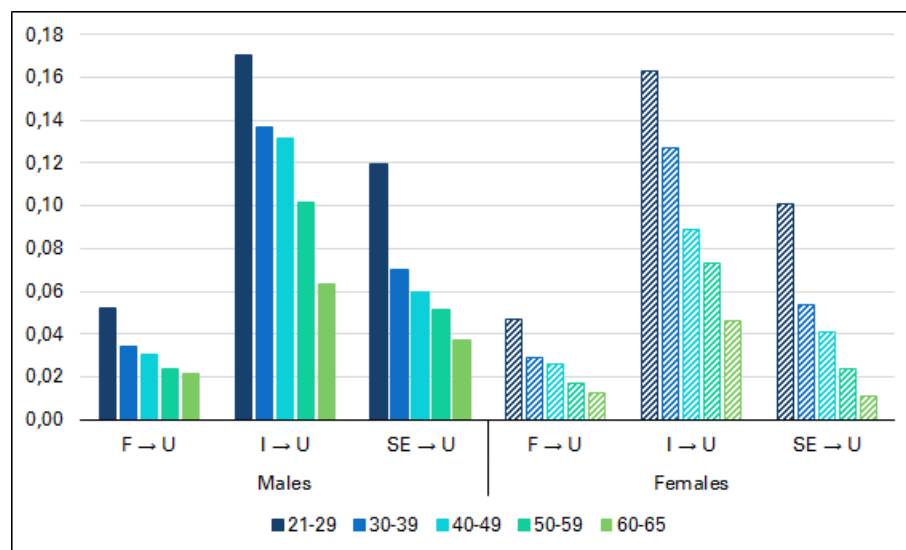
Note: Author's estimations results.

Figure 9 – Propensities to flow into Unemployment
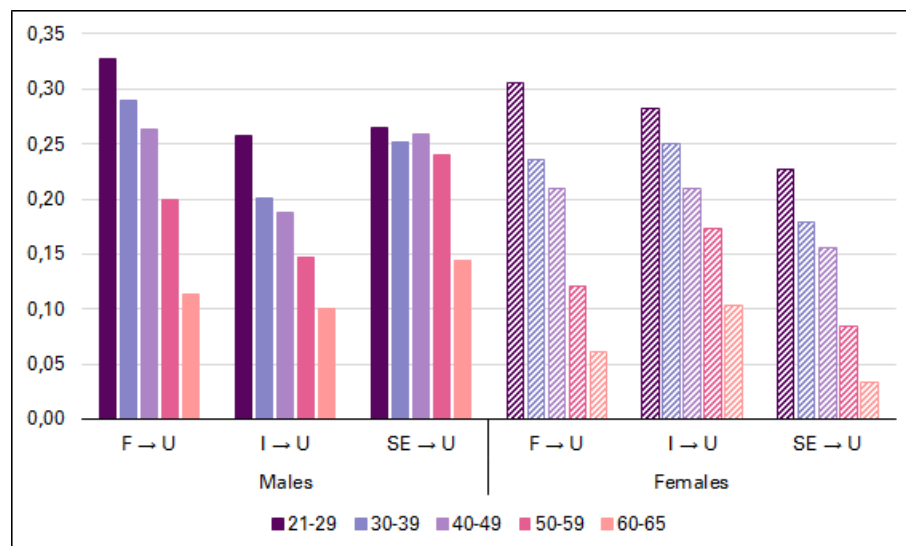
Note: Author's estimations results.

Although the definitions of informality and precarious employment are not exactly comparable, Fougère e Kamionka (1992) found that transition rates (unadjusted for turnover) from precarious employment into unemployment exceed the rates from non-precarious employment into unemployment for all age groups. The same pattern appears

in Neri et al. (1997), who suggest that informal workers flow into unemployment more frequently, although they flow out of unemployment more intensely too. Bosch e Maloney (2007) point out that the shorter spells of employment in the informal sector may indicate that informal workers are less attached to the labor market, or that they leave their jobs in order to search for a better opportunity. On the employer side, there may be a tendency of firms to destroy informal positions due to the lack of protections and therefore the reduced firing costs compared to formal jobs.

Figure 10 shows the effect of education on the transition intensities from each employment state into unemployment. The upper panels reveal that the effect of a High School diploma is not significant for the transitions from self-employment to unemployment for females. For males, the hazard ratios of High School and College are significant and less than one for all age groups, which means that having either degree significantly decreases the chances of leaving self-employment to become unemployed. College educated females aged 21-29 and 30-39 flow from self-employment into unemployment significantly less intensely than their counterparts with less than High School. For women in the older age groups it is not possible to distinguish the self-employment to unemployment transition intensities of the different education groups as the hazard ratios are not significantly different from one.

The middle panels of Figure 10 indicate that higher education levels are associated with lower transitions from informality to unemployment. High School educated workers aged 21-29 transition significantly less intensely from informality to unemployment. The other age groups have non-significant hazard ratios of High School. College educated males of all age groups also transition less intensely into unemployment form informality. The bottom panels show that a High School diploma is associated with lower transition intensities from formality to unemployment only for younger males (age groups 21-29 and 30-39). A College degree has a significant negative effect on this transition for younger males and females, while non-significant for the older workers. The education attainment has an overall small effect on flow rates into unemployment, except for self-employed males who are significantly less likely to enter unemployment and formally employed young females who flow less intensely into unemployment.

4.2.3 Flows into Self-employment

Figures 11 and 12 display the transition intensities and propensities to flow into self-employment from formality and informality as well as from unemployment. Men are much more likely to flow into self-employment than women from all three departure states. The adjustment for the turnover rate does not change the pattern: males' propensity to flow into self employment largely exceed females'. Over 40 percent of males aged 30-39 or

Figure 10 – Hazard Ratios of High School and College - Transitions from Employment to
Unemployment
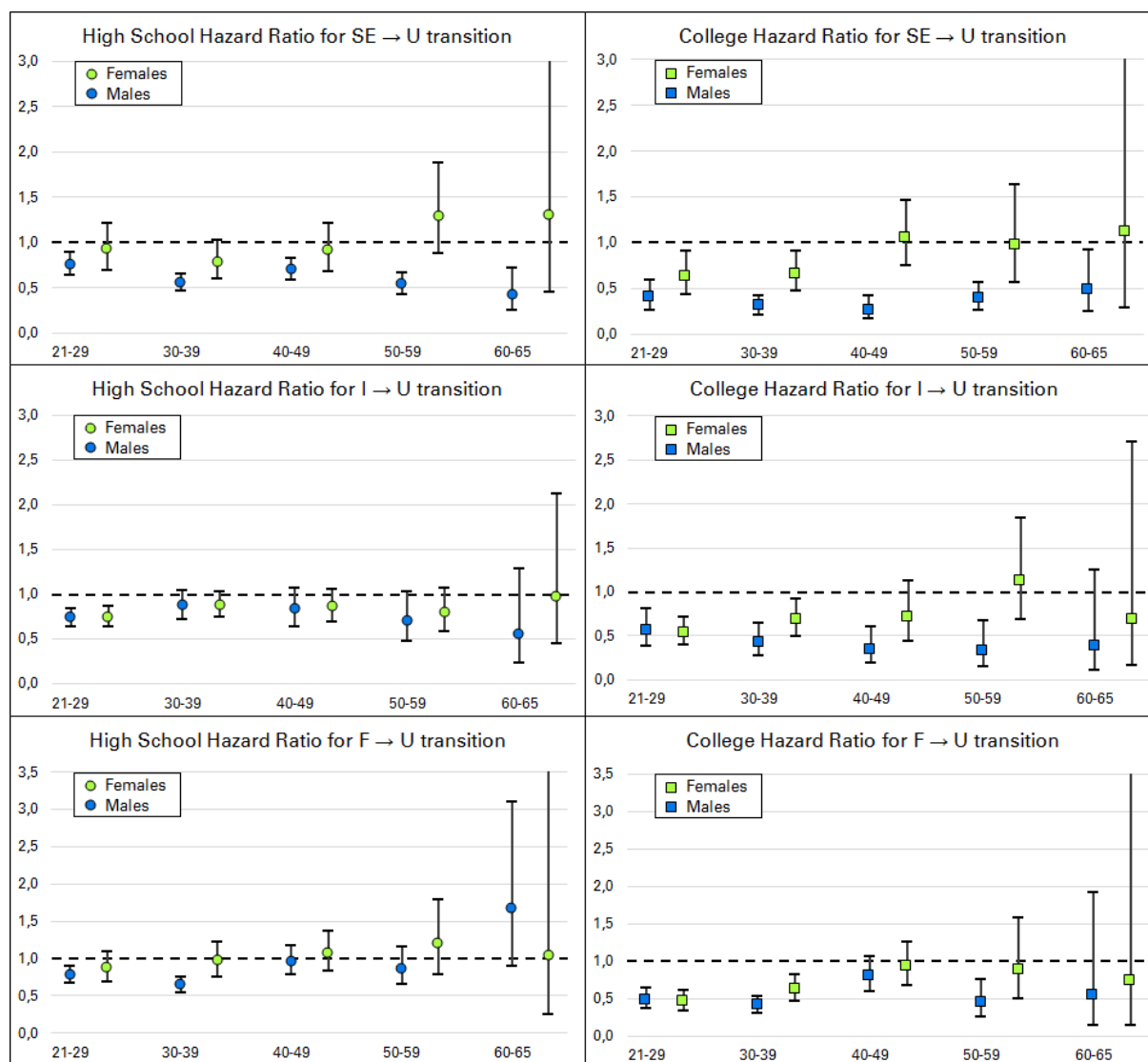
Note: Confidence intervals at the 95% level assuming normality of the log-effect. Hazard ratios calculated exponentiating the estimated effect of the covariate on the log-transition intensity. Some upper limits of the confidence intervals of non-significant hazard ratios were omitted to allow a better visualization of the estimates.

40-49 leaving informality end up self-employed while the share of females is 20 percent. There seems to be a very dynamic channel between informality and self-employment for males as the transitions back into informality from self-employment are also very intense for this group. For all age and gender groups, flows between formality and self-employment are relatively low compared to the other departure states. When the transition intensities are adjusted for the turnover in each state, the pattern also remains unchanged: flows from unemployment and informality into self-employment exceed flows from formality into self-employment for both men and women. The propensities indicate, however, that flows from informality into self-employment are higher than flows from unemployment.

As suggested by Evans e Jovanovic (1989), younger individuals should be less likely

to transition into self-employment because of credit constraints or barriers to entry into this sector. This seems to be the case of Brazilian males, whose transition intensity and propensity to flow from unemployment and informality into self-employment increases with age. Similarly to Bosch e Maloney (2007)'s results, flow rates into self-employment appear concave in age, a clear pattern for males transitioning from unemployment and informality. Prime-age males (30-59) are the most likely to enter self-employment from all three departure states.

Figure 11 – Transition Intensities into Self-Employment
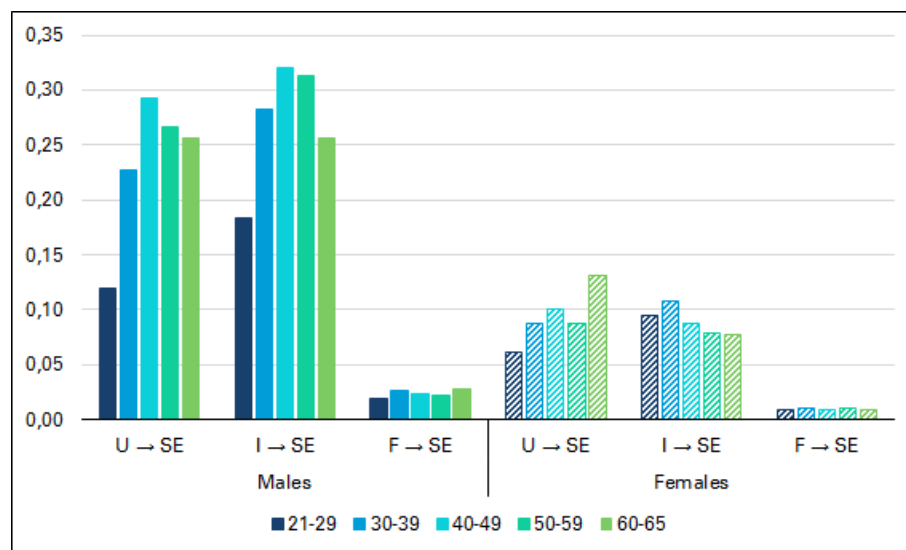
Note: Author's estimations results.

Figure 12 – Propensities to flow into Self-Employment
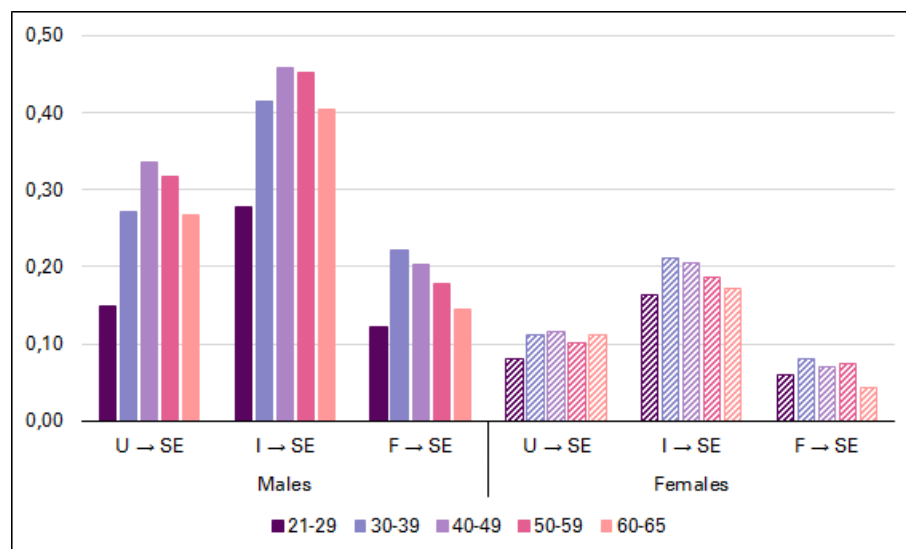
Note: Author's estimations results.

The hazard ratios of the education covariates for the transitions into self-employment are displayed in Figure 13. Education is associated with a lower transition intensity from unemployment to self-employment for males of all ages (upper panels). Both High School

and College have a similar effect on this transition: unemployed males with either degree flow at similar rates into self-employment, which is half the rate of those with less than High School. For females, a High School diploma does not affect significantly the transition into self-employment and a College degree only impacts positive and significantly the 50-59 age group. It seems like self-employment does not figure as a sector of last resort after search for the most qualified workers as they are less likely to quit searching for a job to become self-employed.

When the departure state is informality (middle panels of Figure 13), the effect of education for males and females is very different. A High School diploma is associated with a higher transition intensity between informality and self-employment for females of all age groups except 21-29. The effect of College is even greater. Consider females aged 30-39: compared to a worker with less than High School, a worker who has completed High School is 64 percent more likely to flow from informality to self-employment; a College educated worker is 3.7 times more likely to make this transition. Education for male informal workers, on the other hand, only slightly increases the transition intensity into self-employment. A male aged 30-39 flow into self-employment from informality only 2 percent more intensely if he has completed High School compared to those who have not, a non-significant increase. If he is College educated, the intensity increases 16 percent.

Finally, education seems to play a minor role on the transitions from formality into self-employment (bottom panels). Both the College and the High School hazard ratios are only significant and negative for males aged 30-39 and 40-49. The very low transition intensities from formality into self-employment may have made it difficult for the model to detect a significant effect of education on this flow. Hirata e Machado (2010)'s results suggest that highly educated workers are attracted to leave formal salaried jobs to become self-employed or open small businesses. This sector is also attractive to the less qualified workers who expect an increased income compared to other sectors of employment.

4.2.4   Flows between Formality and Informality

The segmentation hypothesis has clear implications in terms of transitions between the formal and informal sectors. In a segmented labor market, workers queue for formal positions, perceived as more advantageous due to higher wages and other non-pecuniary characteristics, which implies that transitions from the informal to the formal sector would exceed the flows from the formal to the informal sector. If, on the other hand, the labor market is integrated, informality is just another characteristic of a job and does not necessarily imply a lower quality of the position. Therefore the flows on both directions would be symmetrical. Figure 14 shows the transition intensities between formality and informality. At first glance, flows from informality to formality are much more intense

Figure 13 – Hazard Ratios of High School and College - Transitions into Self-Employment
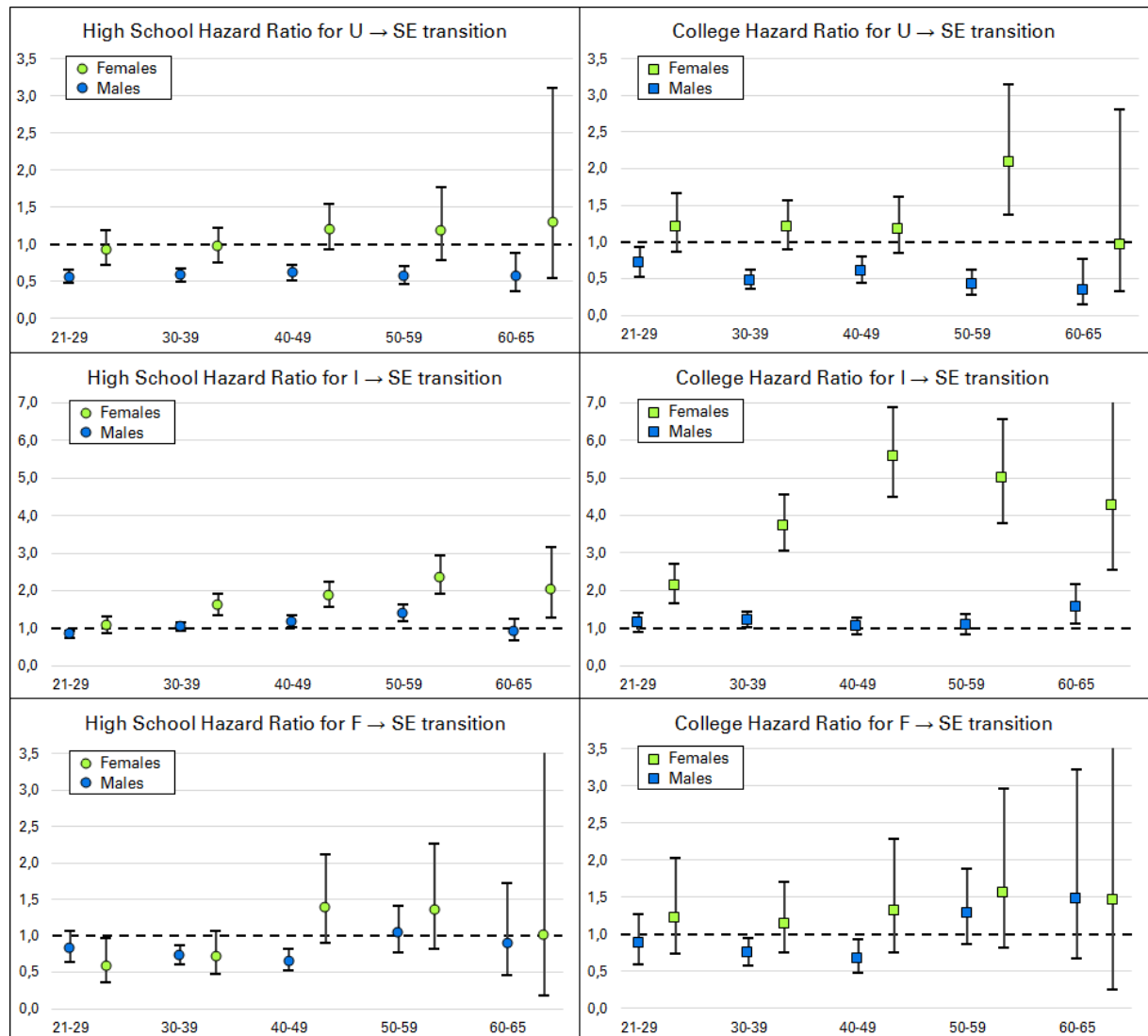

Note: Confidence intervals at the 95% level assuming normality of the log-effect. Hazard ratios calculated exponentiating the estimated effect of the covariate on the log-transition intensity. Some upper limits of the confidence intervals of hazard ratios were omitted to allow a better visualization of the estimates.

than the other way around. A 30-39 years old male is five times more likely to flow from the informal to the formal sector than from the formal to the informal sector. This large asymmetry can be interpreted as a potential segmentation of the labor market, where workers queue for formal sector jobs while informally employed.

Most studies for the Brazilian data find this same pattern. Barros, Sedlacek e Varandas (1990), one of the first studies on mobility and segmentation, calculate discrete-time transition probabilities, not controlling for worker characteristics, and find that the probability of transitioning from the informal to the formal sector in a year is up to ten times greater than the probability to flow the other way around (45.8 vs. 4.7 percent, for the period 1984-1987). Their analysis is restricted to household head males with education up to High School in the São Paulo metropolitan area, and only consider two

Figure 14 – Transition Intensities between Formality and Informality
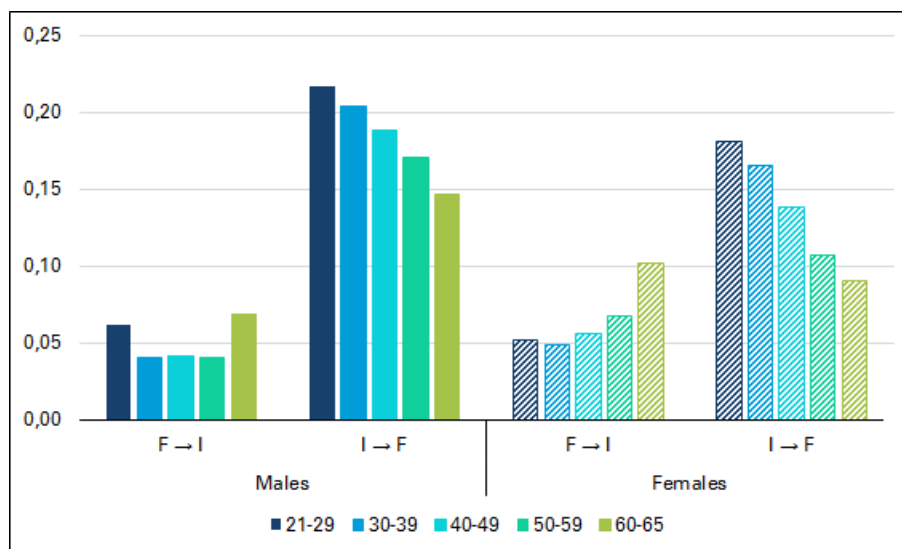
Note: Author's estimations results.

states an individual can be in each observation: formal and informal employment. Curi e Menezes-Filho (2006) considered a state-space with five possible labor market states and observed that the chances of an informal worker to be employed in the formal sector after one year was 21 percent in the period 1992-2000, while the reverse flow probability was 9 percent. Their estimates are comparable to the transition intensities calculated in this study. Their conclusion, however, is that the segmentation in the Brazilian labor market is low, as they combine the analysis of mobility patterns and wage differentials.

Despite differences in methodology and scope, most studies of the Brazilian labor market recognize that the turnover rate in the informal sector is substantial compared to the formal sector. The duration of an employment spell in the informal sector is much shorter than in the formal sector. Table 6 indicates that the average expected duration of a spell in the formal sector can be up to six times longer than a spell in the informal sector. The differences in turnover rates, and therefore in the mean duration of spells in each sector, demonstrates the need to adjust for the turnover in order to evaluate more precisely the mobility patterns between formality and informality.

Table 6 – Mean Sojourn Time in Formality and Informality by
age and gender

	Males				
	21-29	30-39	40-49	50-59	60-65
Informal Salaried	1.5	1.5	1.4	1.5	1.6
	(0.0204)	(0.0238)	(0.0263)	(0.0314)	(0.0569)
Formal Salaried	6.3	8.5	8.6	8.3	5.3
	(0.0898)	(0.1329)	(0.1586)	(0.1905)	(0.2074)
	Females				
	21-29	30-39	40-49	50-59	60-65
Informal Salaried	1.7	2.0	2.4	2.4	2.2
	(0.0269)	(0.0329)	(0.0421)	(0.0485)	(0.0850)
Formal Salaried	6.5	8.2	8.0	7.1	4.9
	(0.1109)	(0.1429)	(0.1587)	(0.1792)	(0.2636)

Note: Average number of quarters an individual is expected to spend in the formal and informal sectors before transitioning into any of the four other states. Standard Errors in parenthesis.

While the transition intensity from formality to informality is much lower than the other way around, when the rates are adjusted for the turnover a different pattern emerges, particularly for females: the propensity to flow from formality to informality is higher than the propensity to flow the other way (Figure 15). A third of the females aged 30-39 leaving informality enter the formal sector while 40 percent of females of the same age group who leave formality enter the informal sector. The propensity to transition from formality to informality does not vary much with age for males, but for females it is positively correlated to age. The fact that females increasingly flow from formal to informal positions as they age may reflect gender discrimination in the formal sector as well as a preference for the sector as it can be more flexible and easy to balance with household responsibilities.

Similarly to the results of this study, Bosch e Maloney (2007) observed that informal-formal transition intensities exceed the transitions the other way around while the propensities display the opposite pattern in Brazil. Here, it is possible to notice that this reversal is much more prominent for females, especially those of the older age groups. It is important to note that the period considered in this study is of great weakness in the Brazilian labor market as the economy was slowly recovering from one of the deepest recessions in the country's recent history. The high propensities to flow into the informal sector among females may reflect the fragility of their position in the labor market during downturns. Female workers leaving formal positions were possibly not finding other formal jobs and ended up informally employed to avoid unemployment, especially older workers, who already face difficulty to find a new position upon dismissal.

Figure 15 – Propensities to flow between Formality and Informality
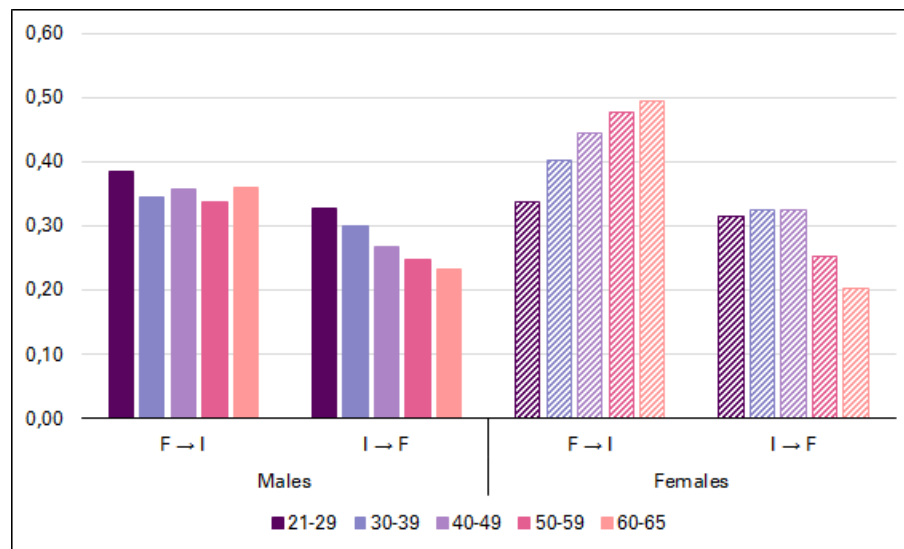
Note: Author's estimations results.

Figure 16 displays the effect of education on the transition rates between formality and informality. The upper panels show that education is positively correlated to the transition intensities from the informal to the formal sector. For both males and females, a High School diploma is associated with a 70 percent increase in the transition intensity, varying slightly with age. A College degree, on the other hand, has different effects on the informal-formal transition for males and females and across age groups. For young men and women, a College degree more than doubles the transition intensity from an informal to a formal position. In fact, young males and females behave similarly in their transitions into formality.The effect of College in the informal-formal flow is much greater for females aged 30-39, 40-49 and 50-59. Transitions of females of these age groups are almost three times more intense when they are College educated, compared to their counterparts with less than High School. College educated men of these age groups, on the other hand, transition into formality only 75 percent more intensely than those with less than High School. College educated females aged 30-59 behave very similarly to males with High School and College in their transitions from informality to formality. Although Royalty (1998) does not distinguish between formal and informal jobs, her overall conclusion is that highly educated women behave similarly to men in their job-to-job transitions too. The author also suggests that education may have a positive effect on quitting to jobs that offer greater opportunities. If we consider that formal jobs are better than informal ones, and that College educated women flow two to three times more intensely to formal jobs than their low educated counterparts, we reach a similar conclusion for the Brazilian data.

The bottom panels of Figure 16 show that the effect of education on the transition rates from formality to informality is mostly negative, except for older males, for whom the effect of both High School and College is positive. Workers who have completed High

School or College are at lower risk of transitioning into the informal sector from a formal position. This pattern is consistent with the most qualified workers avoiding informal salaried jobs.

Figure 16 – Hazard Ratios of High School and College - Transitions between Formality and Informality
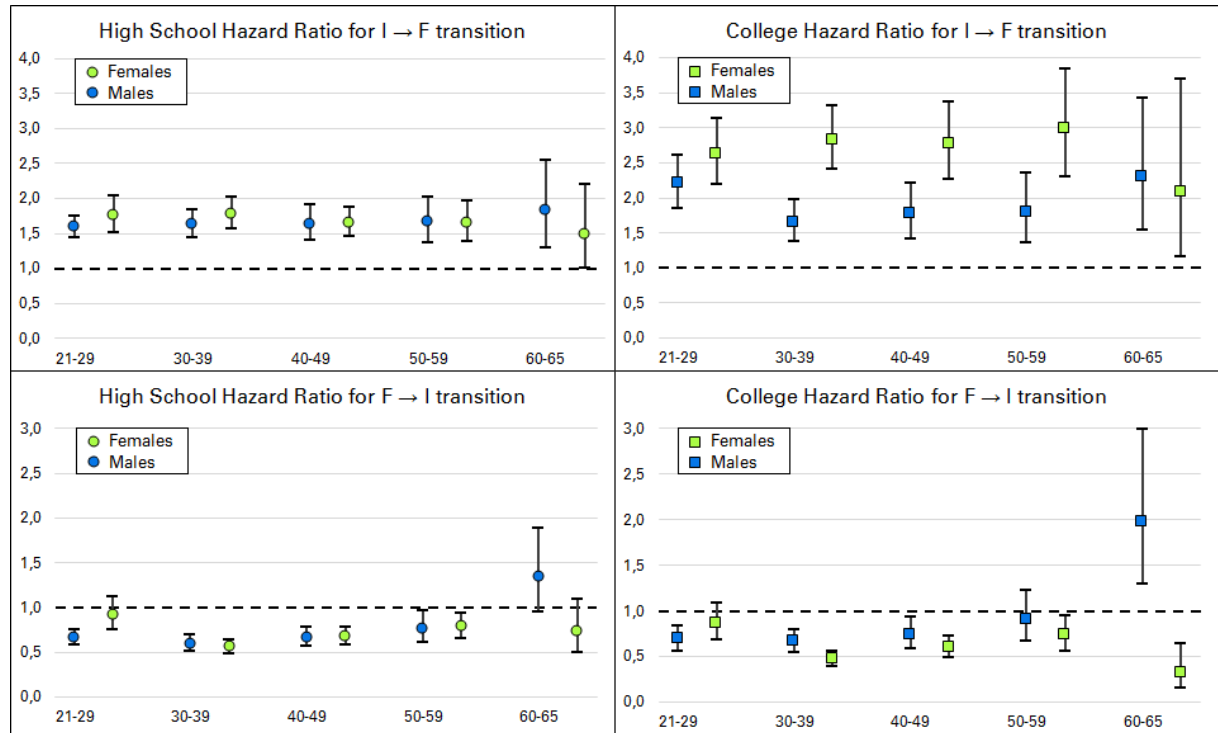
Note: Confidence intervals at the 95% level assuming normality of the log-effect. Hazard ratios calculated exponentiating the estimated effect of the covariate on the log-transition intensity. Some upper limits of the confidence intervals of hazard ratios were omitted to allow a better visualization of the estimates.

As for the asymmetry in the flow rates across educational levels, Gong e van Soest (2002) present evidences that segmentation would occur among the higher educated workers in Mexico, while the lower educated behaved more like the integrated view. In order to evaluate the asymmetry of the flows between formality and informality, Figure 17 displays the intensities (left panels) and propensities (right panels) to flow between the two sectors disaggregating by education level as well as gender and age. Workers with less than High School are those with the most symmetrical transition intensities, although flow rates from informality to formality are still greater than the other way around. For High School and College educated workers, the asymmetry is much more prominent. Considering the propensities, however, the asymmetry largely disappears for High School and College educated workers and is reversed for those with less than High School. The propensities therefore provide little evidence of segmentation among the higher educated workers.

The larger propensity to flow from formal to informal jobs for those with less than High School may also be a reflect of the fragile position of lower educated workers when the labor market is weak, as they are usually the most affected by layoffs in the formal

sector. Older females with less than High School are the most likely to flow from formal to informal jobs both in terms of intensities and propensities. Out of the 30-39, 40-49 and 50-59 years old females who transition out of formality, almost 50 percent of them enter the informal sector. Among 60-65 year-olds, the share is 54 percent.

Figure 17 – Intensities and Propensities to flow between Formality and Informality, by education level
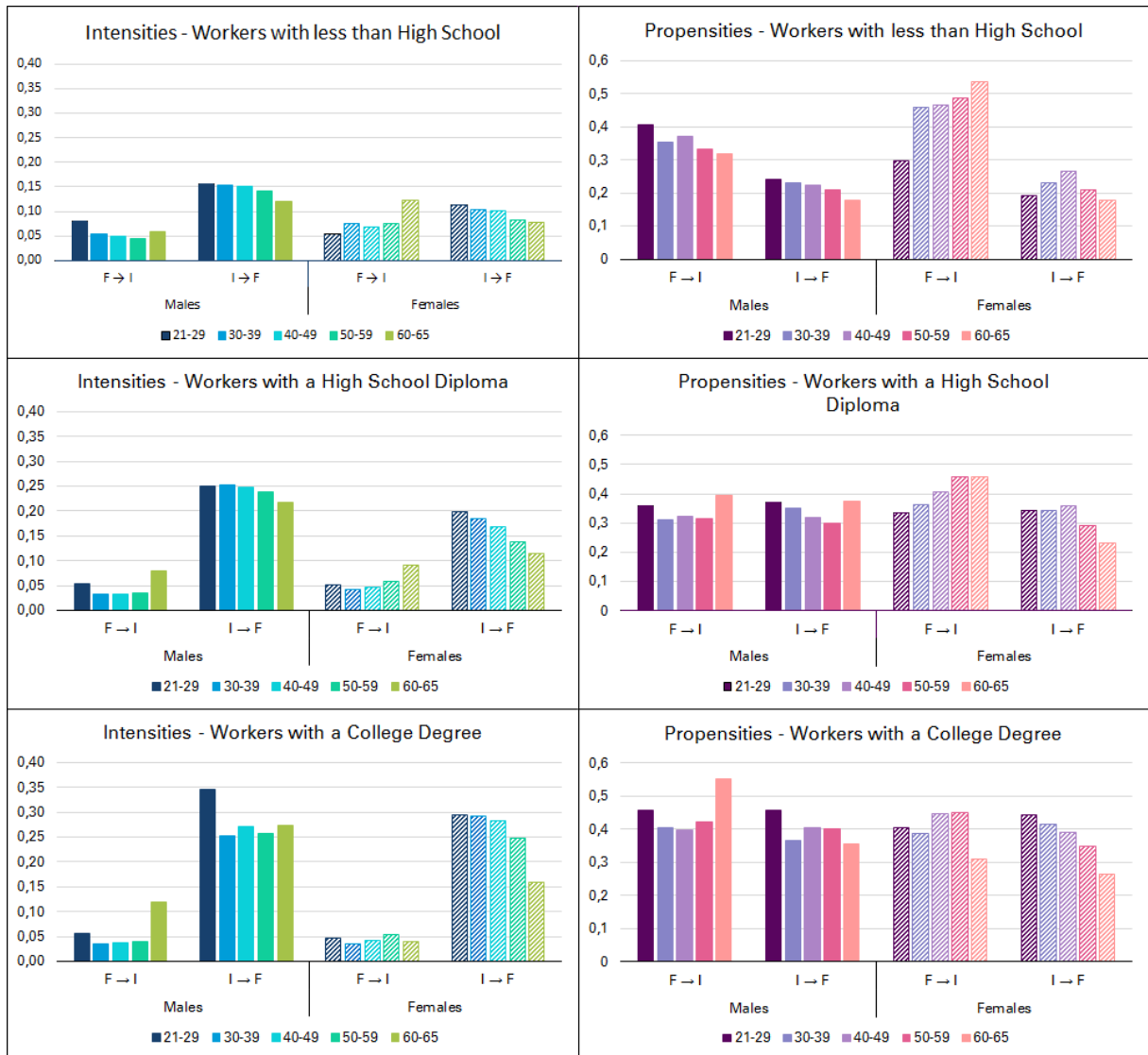
Note: Author's estimations results.

5 Discussion

Age, gender and education are deeply connected to individual labor market outcomes. In this study I have estimated transition rates between employment and non-employment states highlighting these three dimensions, which I found to impact significantly the mobility patterns of Brazilian workers. The continuous-time framework, where the labor market paths are governed by a time-homogeneous Markov process, has proven adequate to reproduce the patterns observed in the data. The analysis of the rates at which workers transition between states sheds light on the groups that are at higher risk of making each transition and contributes to the characterization and measurement of labor market dynamics. The adjustment of the flow rates for the turnover in the departure state helps identify whether a group of workers is indeed more prone to making a transition between two specific states or whether the group is just very mobile and display an overall high turnover rate compared to other groups. The relative magnitudes that I, following Bosch e Maloney (2007), call "propensity" to flow provided interesting insights on the importance of the different turnover patterns.

Of particular interest was the relationship between educational levels and mobility across the five labor market states considered, as well as its interaction with age and gender. With the estimation of the hazard ratios it has become clear that some transitions are equally affected by the completion of High School or College while in some cases the educational attainment only significantly impacts the flow rates of females and not of males, or the flow rates of the young and not of the old workers. Considering the participation margin, the results suggest a measure of the increased opportunity cost of inactivity associated with higher educational attainment. The fact that a College degree decreases the transition rates into inactivity more than a High School diploma can be interpreted as an indication of such cost. In light of the estimated flow rates into inactivity, College educated women of younger age groups are just as attached to the labor force as males of all educational levels. This pattern reflects on the participation rate of highly educated young women, which is comparable to that of males. As they age, even the most qualified female workers become more likely to flow into inactivity compared to males, and their participation in the labor force weakens.

Education affects the unemployment exit rates differently depending on the arrival state and the worker's age. While educational attainment seems to significantly prevent workers of all demographic groups from flowing into informal jobs, it only increases the chances of transitioning into a formal job for the young. Workers with less than High School are the most likely to flow into the informal sector when they are young, corroborating the idea that informality is a port of entry into employment particularly important for the least

educated workers in Brazil. Barriers to entry into the formal sector from unemployment seem more prominent for workers with less than High School and mostly disappear for High School and College educated workers, who are just as likely to flow into formality and informality upon search. Once employed, the highly educated workers are not always less likely to flow into unemployment. Men are the most affected by higher education as their transition rates into unemployment are significantly reduced if they have completed College. On the other hand, a High School diploma for a woman does not reduce her chances of flowing into unemployment from all sectors of employment and a College degree only decreases the flow rates of the young.

Self-employment also displays barriers to entry, particularly for young workers. The most salient feature of the flows into self-employment, however, is the difference between males and females. Brazilian men are much more likely to become self-employed than women, either coming from the other sectors of employment or from unemployment. There seems to be a channel between informality and self-employment particularly dynamic for males. Almost half of prime-age male workers who leave informality end up self-employed and over 40 percent of males who leave self-employment end up in informality. Among females, the shares are respectively twenty and thirty percent. At the same time, women are the most positively affected by education in their informality to self-employment transitions. A College educated female aged 40-49 can flow up to five times more intensely from informality into self-employment compared to their lower educated counterpart and they flow just as intensely as males of the same age and education group. The similarities between highly educated women and men of all education groups is such that the distribution of stocks of highly educated males and females across employment states is similar for all age groups.

Significant mobility between formality and informality indicate that the two sectors communicate intensely. The asymmetry of the transition intensities, which would suggest a segmentation of the labor market, does not hold when I adjust for the turnover rates. In fact, the propensities to flow from formality into informality is higher than the other way around, particularly for the least qualified workers. The propensities to flow between formal and informal positions are virtually symmetrical for the young and for College educated workers, which can be interpreted as evidences of an integrated rather than segmented labor market for these groups. The effect of higher education on formal-informal transitions is significantly negative and similar across most age and gender groups. A College degree, however, affects differently males and females in their transitions from informal to formal jobs. Again, highly educated females behave very similarly to males, as they are just as likely to flow from informality to formality.

The mobility patterns registered in this study highlight the importance of education on individual labor market paths as well as its impact on males and females of different

ages. The methodology employed has proven advantageous as it attempts to overcome some issues associated with discrete-time descriptions of the labor market. Further developments could explore the consequences of relaxing the time-homogeneity assumption, allowing the transition rates to vary with the time spent in each state. Another possibility is to consider mixed Markov models, also known as mover-stayer models such as Beffy, Coudin e Rathelot (2014)'s. The analysis can also benefit from the inclusion of unobserved heterogeneity in the proportional hazards model, which could potentially improve the fit of the model. The results of the most simple Markov model fitted to the Brazilian data in this study have contributed to the characterization of the Brazilian labor market mobility patterns, yet the framework can still be enhanced to account for other aspects of the data.

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APPENDIX A – Data

The *Pesquisa Nacional por Amostra de Domicílios Contínua* (PNADC) is one of the most important sources of information about the Brazilian labor market. The dataset is available online from the Brazilian Institute of Geography and Statistics (IBGE) website. The survey was introduced in 2012 in a 1-2(5) rotating panel scheme, in which data is collected through five interviews conducted with household members. Each household is interviewed in a month, leaves the sample for the next two months and returns to the sample for another interview. This is repeated five times so that the first and the fifth interviews are one year apart.

The survey was designed to follow households, not individuals. Therefore, if individuals move out, for example, they are lost due to attrition. There is no key variable that identifies them in the panel. However, the household can be identified, and other variables can be used to track individuals such as date of birth, sex, education, and others. Ribas e Soares (2008) propose an algorithm to identify individuals throughout the interviews which was applied to the dataset to obtain a longitudinal panel at the individual level. To determine the individual transitions, all pairs of interviews were considered so that the interval between two observed states is one quarter. Because it is necessary to have the information on individual's states in two periods, those who did not complete at least two consecutive interviews, were excluded from the sample.

Individuals who stated they were employers, employed in the public sector or in the military, or unpaid workers in any interview were excluded. Those whose condition in the household was either domestic worker, domestic worker relative or pensioner were dropped from the sample. Individuals with missing data for ethnicity were also dropped, as well as the group of individuals that declared they were indigenous. Individuals living in rural areas were excluded from the sample as well.

The variable that characterizes the states of employment is the "occupation position" (VD4009). Formal workers include private sector employees and domestic workers covered by the labor legislation, that is, those who have the "labor card". Informal workers are employees and domestic workers who do not have the "labor card". The attitude towards job search is the criterion to distinguish between unemployment and inactivity: while unemployed individuals search for work, inactive individuals neither work nor search for work. These states are obtained from the variables VD4001 and VD4002 of the PNADC. Data on education is available from the variable VD3004, which presents the highest level of education achieved.

In this study I consider a sub-sample of the PNACD, a panel covering the period

from the first quarter of 2017 to the first quarter of 2019. Five rotating groups are part of this panel and each one of them start the survey in a different quarter, as in Table 7. In the model estimation, I do not take into account this difference in chronological time of the interviews; I pool all five groups together and estimate the flow rates regardless of the quarter in which the transitions occurred.

Table 7 – Rotating groups of Panel 6

	Interview 1	Interview 2	Interview 3	Interview 4	Interview 5
2017.Q1	Group 1				
2017.Q2	Group 2	Group 1			
2017.Q3	Group 3	Group 2	Group 1		
2017.Q4	Group 4	Group 3	Group 2	Group 1	
2018.Q1	Group 5	Group 4	Group 3	Group 2	Group 1
2018.Q2		Group 5	Group 4	Group 3	Group 2
2018.Q3			Group 5	Group 4	Group 3
2018.Q4				Group 5	Group 4
2019.Q1					Group 5

The sample was split into ten subgroups according to the individual's gender and the age bracket they belong to. Table 8 displays the number of observations in each sub-sample. Each individual may appear up to five times in the sample, therefore the number of individuals is a fraction of the number of observations.

Table 8 – Sample sizes

	21-29	30-39	40-49	50-59	60-65	Total
Male	129,724	118,142	100,940	86,623	41,918	537,434
Female	133,255	130,844	116,167	107,173	55,939	600,762

APPENDIX B – Tables

Table 9 – Distribution of employed workers across employment states per subsample and education level (%)

		Males				
		21-29	30-39	40-49	50-59	60-65
	Self-Employed	24.8	36.0	44.3	51.2	59.1
Less than High School	Informal	31.7	21.2	16.3	13.8	14.4
	Formal	43.5	42.8	39.5	35.0	26.5
	Self-Employed	17.1	27.0	34.3	44.4	53.8
High School Diploma	Informal	19.2	10.5	8.1	8.2	12.3
	Formal	63.8	62.4	57.6	47.4	33.9
	Self-Employed	20.3	26.0	31.9	42.3	54.9
College Degree	Informal	13.5	8.8	8.3	9.3	13.7
	Formal	66.3	65.3	59.8	48.5	31.4
		Females				
		21-29	30-39	40-49	50-59	60-65
	Self-Employed	22.7	24.0	25.9	33.7	46.9
Less than High School	Informal	36.6	36.8	35.3	33.4	32.5
	Formal	40.7	39.2	38.8	32.9	20.6
	Self-Employed	15.2	23.7	29.8	38.9	53.0
High School Diploma	Informal	22.6	17.2	17.7	18.7	20.8
	Formal	62.2	59.1	52.5	42.4	26.2
	Self-Employed	18.1	24.0	30.3	41.3	51.9
College Degree	Informal	14.1	9.1	9.2	11.2	13.2
	Formal	67.9	66.9	60.5	47.5	34.9

Note: Author's calculations based on subsamples of Panel 6 from the PNADC dataset. The data collection period is from the first quarter of 2017 to the first quarter of 2019. Sampling weights were not considered.

Table 10 – Baseline transition rates between Employment states, by age and gender

	Age	21-29	30-39	40-49	50-59	60-65
$SE \to I$	Males	0.21	0.13	0.10	0.07	0.06
		(0.0060)	(0.0034)	(0.0028)	(0.0025)	(0.0037)
	Females	0.13	0.09	0.07	0.06	0.05
		(0.0057)	(0.0034)	(0.0030)	(0.0030)	(0.0045)
$SE \to F$	Males	0.05	0.04	0.03	0.02	0.01
		(0.0031)	(0.0019)	(0.0015)	(0.0012)	(0.0019)
	Females	0.03	0.03	0.02	0.01	0.00
		(0.0031)	(0.0019)	(0.0015)	(0.0013)	(0.0015)
$I \to SE$	Males	0.18	0.28	0.32	0.31	0.26
		(0.0053)	(0.0075)	(0.0091)	(0.0105)	(0.0154)
	Females	0.09	0.11	0.09	0.08	0.08
		(0.0041)	(0.0041)	(0.0036)	(0.0040)	(0.0079)
$I \to F$	Males	0.22	0.20	0.19	0.17	0.11
		(0.0051)	(0.0059)	(0.0065)	(0.0073)	(0.0111)
	Females	0.18	0.17	0.14	0.11	0.09
		(0.0051)	(0.0046)	(0.0041)	(0.0042)	(0.0077)
$F \to SE$	Males	0.02	0.03	0.02	0.02	0.03
		(0.0011)	(0.0011)	(0.0013)	(0.0016)	(0.0037)
	Females	0.01	0.01	0.01	0.01	0.01
		(0.0009)	(0.0008)	(0.0009)	(0.0013)	(0.0032)
$F \to I$	Males	0.06	0.04	0.04	0.04	0.07
		(0.0018)	(0.0014)	(0.0016)	(0.0020)	(0.0054)
	Females	0.05	0.05	0.06	0.07	0.10
		(0.0019)	(0.0016)	(0.0019)	(0.0028)	(0.0089)

Note: Author's estimations results. Standard Errors in parentheses.

Table 11 – Baseline transition rates in and out of Unemployment, by age and gender

	Age	21-29	30-39	40-49	50-59	60-65
$SE \rightarrow U$	Males	0.12	0.07	0.06	0.05	0.04
		(0.0052)	(0.0030)	(0.0025)	(0.0023)	(0.0033)
	Females	0.10	0.05	0.04	0.02	0.01
		(0.0059)	(0.0032)	(0.0028)	(0.0023)	(0.0028)
$I \rightarrow U$	Males	0.17	0.14	0.13	0.10	0.06
		(0.0063)	(0.0068)	(0.0076)	(0.0077)	(0.0097)
	Females	0.16	0.13	0.09	0.07	0.05
		(0.0064)	(0.0056)	(0.0046)	(0.0046)	(0.0075)
$F \rightarrow U$	Males	0.05	0.03	0.03	0.02	0.02
		(0.0018)	(0.0014)	(0.0015)	(0.0017)	(0.0036)
	Females	0.05	0.03	0.03	0.02	0.01
		(0.0020)	(0.0015)	(0.0016)	(0.0018)	(0.0043)
$U \rightarrow SE$	Males	0.12	0.23	0.29	0.27	0.26
		(0.0048)	(0.0086)	(0.0107)	(0.0117)	(0.0225)
	Females	0.06	0.09	0.10	0.09	0.13
		(0.0032)	(0.0045)	(0.0062)	(0.0086)	(0.0273)
$U \rightarrow I$	Males	0.22	0.21	0.20	0.17	0.12
		(0.0068)	(0.0095)	(0.0100)	(0.0108)	(0.0175)
	Females	0.15	0.17	0.19	0.21	0.22
		(0.0049)	(0.0066)	(0.0086)	(0.0127)	(0.0342)
$U \rightarrow F$	Males	0.13	0.15	0.13	0.09	0.04
		(0.0044)	(0.0065)	(0.0069)	(0.0067)	(0.0088)
	Females	0.09	0.09	0.08	0.05	0.01
		(0.0034)	(0.0043)	(0.0052)	(0.0059)	(0.0096)

Note: Author's estimations results. Standard Errors in parentheses.

Table 12 – Baseline transition rates in and out of Inactivity, by age and gender

		21-29	30-39	40-49	50-59	60-65
$SE \to N$	Males	0.07	0.04	0.04	0.07	0.15
		(0.0038)	(0.0021)	(0.0019)	(0.0023)	(0.0051)
	Females	0.18	0.13	0.13	0.20	0.28
		(0.0066)	(0.0041)	(0.0039)	(0.0047)	(0.0094)
$I \to N$	Males	0.09	0.06	0.06	0.11	0.17
		(0.0045)	(0.0047)	(0.0051)	(0.0073)	(0.0141)
	Females	0.14	0.11	0.11	0.16	0.23
		(0.0058)	(0.0054)	(0.0050)	(0.0062)	(0.0135)
$F \to N$	Males	0.03	0.02	0.02	0.03	0.07
		(0.0013)	(0.0010)	(0.0011)	(0.0017)	(0.0051)
	Females	0.05	0.03	0.03	0.05	0.08
		(0.0018)	(0.0014)	(0.0016)	(0.0023)	(0.0079)
$U \to N$	Males	0.34	0.25	0.25	0.31	0.54
		(0.0075)	(0.0090)	(0.0098)	(0.0119)	(0.0298)
	Females	0.45	0.44	0.49	0.53	0.81
		(0.0078)	(0.0092)	(0.0122)	(0.0177)	(0.0593)
$N \to SE$	Males	0.05	0.11	0.13	0.09	0.07
		(0.0032)	(0.0067)	(0.0057)	(0.0029)	(0.0024)
	Females	0.05	0.07	0.06	0.05	0.03
		(0.0019)	(0.0021)	(0.0019)	(0.0013)	(0.0012)
$N \to I$	Males	0.09	0.09	0.06	0.03	0.02
		(0.0043)	(0.0070)	(0.0047)	(0.0022)	(0.0015)
	Females	0.05	0.05	0.05	0.03	0.01
		(0.0023)	(0.0023)	(0.0020)	(0.0011)	(0.0009)
$N \to F$	Males	0.03	0.04	0.04	0.02	0.01
		(0.0027)	(0.0045)	(0.0031)	(0.0014)	(0.0009)
	Females	0.02	0.02	0.01	0.01	0.00
		(0.0014)	(0.0013)	(0.0010)	(0.0005)	(0.0003)
$N \to U$	Males	0.36	0.33	0.18	0.08	0.04
		(0.0075)	(0.0111)	(0.0070)	(0.0032)	(0.0021)
	Females	0.26	0.18	0.11	0.04	0.01
		(0.0044)	(0.0037)	(0.0028)	(0.0013)	(0.0008)

Note: Author's estimations results. Standard Errors in parentheses.

Table 13 – Mean Sojourn Time in Employment - Males by education
level

	Self-employment				
	21-29	30-39	40-49	50-59	60-65
Total	2.2	3.6	4.3	4.6	3.8
	(0.0353)	(0.0543)	(0.0696)	(0.0780)	(0.0944)
Less than High School	1.9	2.8	3.7	4.2	3.5
	(0.0434)	(0.0562)	(0.0675)	(0.801)	(0.0967)
High School Diploma	2.3	4.0	5.0	5.3	4.7
	(0.0529)	(0.0943)	(0.1489)	(0.1902)	(0.2734)
College Degree	2.9	4.7	6.1	5.9	4.2
	(0.1611)	(0.2138)	(0.3649)	(0.3817)	(0.3446)
	Informal Salaried				
	21-29	30-39	40-49	50-59	60-65
Total	1.5	1.5	1.4	1.5	1.6
	(0.021)	(0.0238)	(0.0264)	(0.0314)	(0.0569)
Less than High School	1.5	1.5	1.5	1.5	1.5
	(0.0296)	(0.0307)	(0.0306)	(0.0349)	(0.0595)
High School Diploma	1.5	1.4	1.3	1.2	1.7
	(0.0278)	(0.0353)	(0.0456)	(0.0579)	(0.1420)
College Degree	1.3	1.4	1.5	1.6	1.3
	(0.0689)	(0.0726)	(0.0988)	(0.1253)	(0.1357)
	Formal Salaried				
	21-29	30-39	40-49	50-59	60-65
Total	6.3	8.5	8.6	8.3	5.3
	(0.0898)	(0.1329)	(0.1586)	(0.1905)	(0.2074)
Less than High School	5.1	6.5	7.6	7.6	5.3
	(0.1250)	(0.1599)	(0.1884)	(0.2153)	(0.2552)
High School Diploma	6.8	9.7	9.9	9.3	4.9
	(0.1276)	(0.2238)	(0.3021)	(0.3958)	(0.3657)
College Degree	8.3	11.4	11.0	10.7	4.7
	(0.4030)	(0.4837)	(0.6160)	(0.8313)	(0.5289)

Note: Average number of quarters an individual is expected to spend in the formal and
informal sectors before transitioning into any of the four other states. Standard Errors
in parenthesis.

Table 14 – Mean Sojourn Time in Non-employment - Males by education level

| | Unemployment | | | | |
	21-29	30-39	40-49	50-59	60-65
Total	1.2	1.2	1.1	1.2	1.0
	(0.0167)	(0.0216)	(0.0224)	(0.0270)	(0.0421)
Less than High School	1.1	1.0	1.0	1.0	1.0
	(0.0223)	(0.0234)	(0.0238)	(0.0262)	(0.0440)
High School Diploma	1.3	1.3	1.3	1.4	1.2
	(0.0236)	(0.0342)	(0.0461)	(0.0649)	(0.1072)
College Degree	1.3	1.5	1.4	2.0	1.2
	(0.0668)	(0.0860)	(0.1072)	(0.1892)	(0.1611)
	Inactivity				
	21-29	30-39	40-49	50-59	60-65
Total	1.9	1.8	2.5	4.5	8.0
	(0.0272)	(0.0369)	(0.053)	(0.0849)	(0.1997)
Less than High School	1.8	2.2	2.6	3.9	7.3
	(0.0405)	(0.0575)	(0.0615)	(0.0825)	(0.2070)
High School Diploma	2.0	1.4	2.2	5.5	9.7
	(0.0379)	(0.0466)	(0.0877)	(0.2230)	(0.5963)
College Degree	1.6	1.5	2.3	6.9	9.2
	(0.0878)	(0.1022)	(0.1930)	(0.5541)	(0.7617)

Note: Average number of quarters an individual is expected to spend in the formal and informal sectors before transitioning into any of the four other states. Standard Errors in parenthesis.