Self Employment in Developing Countries: a Search-Equilibrium Approach*

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Abstract

Self employment comprises around thirty percent of the workforce in Latin America. Most self employed evade payroll taxes, have low education, and run small businesses requiring low skills. I develop and estimate a life cycle search model where workers can be wage earners in the formal or informal sector, self employed or unemployed. Firms in the formal sector pay payroll and severance taxes, and in the informal sector, they can be fined. The estimated model (i) reproduces well the composition of workers over the life cycle as observed in Brazilian Labour Force data, and (ii) shows that the job value of the self employed is similar to that of informal wage earners. The model is used as a tool to evaluate the welfare impact of labour market policies, where self employment may be an option. When simulating an increase in the cost of informality by ten percent, results showed (i) small impact on employment composition and informality; (ii) significant cost pass-through to wages in the informal sector, meaning a reduction in the lowest wages in the economy, hence higher wage inequality. On the other hand, (iii) it led to substantial improvement in the welfare of formal firms and of all workers. These results prove that taking into account labour market frictions is important in welfare analyses of policies in multisectoral labour markets. As simulations which increase the cost of informality suggest, stricter enforcement of labour regulations (at least to a certain degree) can be a way towards efficient labor markets.

Keywords: Latin America, informal sector, self employment, job search, labour market welfare.
JEL codes: J30; J42; J60.

1 Introduction

Microenterprises are an important source of employment in developing countries. In Latin America, self employment comprises more than thirty percent of all employment. The majority of firms in these countries are owner-only businesses [Maloney et al. 2007]. In Brazil, self employment is a self reported working status. Eighty two percent of those self employed run businesses on their own, with no partners or employees. Eighty five percent do not contribute to social security. Seventy five percent work full time. Sixty four percent are males. Sixty three percent have less than nine years of schooling.[1] In Figure 1, we see a large

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[1] Author's calculations using the Brazilian Labour Force Survey (PME) and Household Surveys (PNAD) for the period 2002-2007.

fraction of self employed workers and informal wage earners.[2] Significantly, we observe a strong dependence of self employment on individuals' age. This results from both increasing entry into and decreasing exit out of self employment. Given age, the average labour income of those self employed is lower than the average wage of formal employees, and this income gap increases as workers get older. Thus, labour incomes alone cannot explain why there are so many self employed workers and why self employment rates increase with age. In this paper, I seek to understand these empirical regularities.

It is very important to distinguish between self employment in developing and developed economies. While financial capital is positively related to starting a business in rich countries [as suggested in Evans and Jovanovic (1989), Hotz-Eakin, Joulfaian and Rosen (1994), Blanchflower and Oswald (1998), Quadrini (2000), and Cagetti and De Nardi (2006)][3], it seems not the primary determinant of business development for the majority of the self employed in developing countries [for example, McKenzie, de Mel and Woodruff (2008) and Banerjee, Duflo, Glennerster and Kinnan (2009)]. Banerjee et al (2009), from randomized experiements conducted in slums in India, show that microcredit policies lead to small increase in business entry.[4] McKenzie et al (2008) show that the individual characteristics of those self employed are more like those of wage earners than of owners of larger enterprises in Sri Lanka. Controlling for these factors, lack of finance seems not an important constraint for most own account workers. Their findings suggest that the self employed are merely workers who wait for good business opportunities that they want to undertake. They seem to learn about these opportunities with their experience in the labour market. In general, they are involved in low scale businesses which require low skills, thus are unlikely to expand and employ other workers. This is consistent with the fact that the majority of those self employed have low education, are older and operate businesses on their own.

In this paper, I present a novel approach to study individuals' employment choices in developing countries, which accounts for the choice of becoming self employed. I develop and estimate a life cycle search model which is extended to have self employment. Search theory consists of a tractable framework which allows for frictions in the labour market in the sense that it takes time for firms and workers to meet. It also allows for frictional entry to self employment in the sense that it takes work experience to learn about good business ideas to pursue as self employed. Workers can be unemployed, self employed, wage earners in the formal sector, or wage earners in the informal sector. The model is thus suitable for analysing developing economies, in which these categories of employment are relevant. To incorporate the idea that entry opportunities to self employment increase with work experience, I allow for nonstationarity in individual trajectories. This is implemented through a life cycle model where potential work experience, like age, varies deterministically and transition parameters are allowed to vary by potential work experience as observed in data.

This approach follows Bowlus and Robin (2003) which estimates a life cycle search model with nonstationary, age dependent, transitions and wage mobility processes. Differently from this paper, they use a partial equilibrium analysis and one sector of employment. Their aim was to study the evolution of labour income inequality in the US, through calculating the individuals' lifetime earnings, that account for earnings and employment risk. In particular, for each individual and year, they compute the present value of lifetime earnings assuming that future shocks to individuals are drawn from the same distribution that older workers face today. I make the same assumption.

To address the issue of workers' heterogeneity, I allow the mobility processes, labour incomes and wage offers distributions to vary according to workers' predetermined characteristics such as sex and education. I

[2]Formal wage earners are registered workers, while informal wage earners are not. Registration entitles the workers to benefits by Employment Laws, such as minimum wage, wage contract, working by 44 hours weekly, paid annual leave etc. It also implies that firms which hire registered workers pay labour taxes, are likely to be registered and to pay corporate taxes.

[3]Using US data, Hurst and Lusardi (2004) test the prediction that liquidity constraints are the source of positive relationship between wealth and starting business. They challenge this view by showing that wealth does not have an impact on business entry for the majority of households in that country. They argue one reason is that the initial level of wealth required to start most businesses is relatively low in the US.

[4]Even in treatment areas, over 70% of households do not take microloans. Of those who take, only 20% start a business.

follow Van den Berg and Ridder (1998) by assuming markets are segmented by sex and by three groups of education and I estimate the model for each of these six markets.

Because the ultimate objective of this paper is to simulate the general equilibrium effects of counterfactual polices, I allow for wages to be determined in equilibrium. I build on the wage posting framework of Burdett and Mortensen (1998). I model ex-ante heterogenous firms which can be in the formal (compliant) sector or in the informal sector following Meghir, Narita and Robin (2010). In relation to their paper, I simplify the model by ruling out the choice of firms in which sector to locate, which would severely complicate the present analysis. Having ex-ante heterogenous firms in an on the job search framework such as this is essential to reproduce the decreasing shape of wage densities as observed in data. [see Bontemps, Robin and van den Berg (2000)] In addition, introducing in the model this source of heterogeneity within sector (formal and informal) allows us to compare formal and informal wages by firm productivity. This can be used to test the compensating wage differentials hypothesis. The formal-informal wage gap by firm type would be in favour of the informal sector workers, because they obtain no mandated benefits by working for an informal firm.

To the best of my knowledge, this is the first paper to study self employment using a life cycle framework with search frictions. A closer approach to this is taken in Albrecht, Navarro and Vroman (2009), following Mortensen and Pissarides (1994). They model an economy with workers who can be formal wage earners or informal self employed. Workers are heteregeneous in the formal sector but have fixed productivity while informal self employed. Formal firms hire only from the formal sector or from unemployment, and their model is stationary, with transition rates which do not depend on the age of the individual. In relation to other models of self employment, my framework also allows frictional entry into self employment, here motivated for the developing countries' context in which self employed are workers who seem to learn with experience about good business opportunities. The main contribution of the paper is a model which accommodates the three main categories of employment of a developing economy which are the formal wage earners, informal wage earners and self employed. Another contribution is that, in contrast to other models of self employment, I abstract from competitive labour market assumptions and allow firms to post wages. The aim is to understand how hiring workers from self employment and having the option to become self employed affect wage dispersion. Consequently, this is also important for analysing the equilibrium effects of labour market policies on wage inequality.[5]

The model is fitted to Brazilian Labour Force data on transitions across sectors of employment and unemployment, and income distributions. Estimates show that a life cycle job search model can reproduce well the composition of workforce by work experience as observed in data. I use the model for counterfactual simulations.

I show that when job offers from informal sector firms become unavailable, most wage earners in that sector become self employed, unemployment increases by a small proportion (3.5pp), and the degree of informality reduces also by a small amount (3pp) as most the self employed evade taxes. Not surprisingly, such policies cause little improvement in workers' welfare. This is expected given that firms cannot move from a sector to another after the policy. Another reason is that on average the lifetime earnings of the self employed are similar to that of the informal wage workers with same experience. Thus, trading the informal wage sector towards more self employment is not expected to improve much welfare.

I also show that increasing the cost of informality by 10% causes small changes in the composition of the workforce across sectors, and increases wage inequality as most of the impact is direct on wages of the informal sector. Nonetheless, there is substantial improvement in workers' and firms' welfare. This results from the existence of self employment which makes the labour force of formal sector firms more sensitive to changes in policies of the informal sector. That labour force increases and corporate taxes reduce in the formal sector causes profits and offered wages to increase in that sector, so workers' welfare to also increase

[5]Wage inequality is particularly high in developing countries. Over the period 2001-2003, the average Gini inequality of hourly wages across Latin American countries was 53. In the US, the Gini index was 41 in 2005 which is one of the highest in developed economies [Sources: IADB and US Census Bureau]

in the formal sector and elsewhere. In other simulations, I analyse the effects of changing in tax/benefit policies. In general, the results show that while the distribution of workers across sectors does not vary much, wage inequality significantly falls by raising minimum wages. In this case however there is a strong trade off between wage inequality and welfare.

The paper is organised as follows. The remainder of this introduction illustrates with some empirical facts about self employment using Brazilian data. Section 2 presents a framework to understand individuals' employment choices, including self employment. Section 3 summarises the data used in the estimation of the model. Section 4 describes the estimation procedure. Section 5 presents the results of estimation. Section 6 uses the model to simulate the impact of counterfactual policies on wage inequality, composition of workforce and welfare in the Brazilian economy. Finally, section 7 concludes.

1.1 Main Facts about Self Employment in Brazil

This section highlights the main empirical facts about self employment using two sources of data: the Brazilian Labour Force Survey (PME) and the Household Annual Surveys (PNAD) for the period 2002-2007.

Self employment is a self reported category of employment in Brazil. It comprises all own account workers, who run businesses on their own, with a partner, and without paid employees. Together, wage earners and those self employed account for the majority of workers.[6] In particular, wage earners can be registered or unregistered. I will call *formal* the registered wage workers and *informal* the unregistered ones.[7]

Table 1 summarises the main characteristics of individuals by employment status. On average, those self employed are more likely to be male, older (as pointed earlier), to have low education, to earn less than formal wage workers, and more than informal wage ones. The majority of those self employed evade payroll taxes, work on their own, and work full time (35 or more hours per week). They are found relative more present in occupations which require low skills such as production, maintenance and repair, and sales. Examples of typical self employment occupations are street vendors, construction workers, maintenance workers, and taxi drivers.

I construct Figure 1 by pooling all years of PME and using information at the individuals' first interview.[8] This figure reports the percentage of workforce by employment status. We see a large fraction of workers under informal employment and self employment. We also observe a strong dependence of self employment on individuals' age.

The increasing fraction of self employed with age is a result of both an increasing entry and a decreasing exit out of self employment. Considering individuals in their first interview and transitions in the subsequent month, Table 2 shows that the most important transitions into self employment are from unemployment. It also shows that transitions out of self employment decrease with age.

One could argue that the dependence of self employment on age is due to cohort effects, whereby older individuals experienced different education and labour market opportunities in their past than youngers do now. If economic conditions in the past had been more conducive to self employment decisions than economic conditions today, then cohort effects would be potentially an explanation for the observed pattern of self employment with age. Figure 16 in Appendix seems to disprove it. The age effect observed in Figure 1 remains strong and the same across cohorts.

It could be that workers' decision of which sector to work is based solely on the potential incomes in each sector. Table 3 summarises labour incomes (net of taxes) by work sector and age. It shows that self employment incomes are around 30 to 40 percent lower than formal sector wages and are higher (lower)

[6] Other categories: employers, unpaid, domestic, and home production workers account for 14% of the workforce.

[7] Registration entitles the workers to benefits by Employment Laws, such as minimum wage, wage contract, working by 44 hours weekly, paid annual leave, maternity leave etc. It also implies that firms which hire registered workers pay labour taxes, are likely to be registered and to pay corporate taxes.

[8] Based on a sample of 700,686 individuals, aged 16 to 65, who are found to be unemployed, self employed or working as an employee (registered or unregistered).

TABLE 1

Descriptive Statistics by Working Status, PME, PNAD 2002-2007

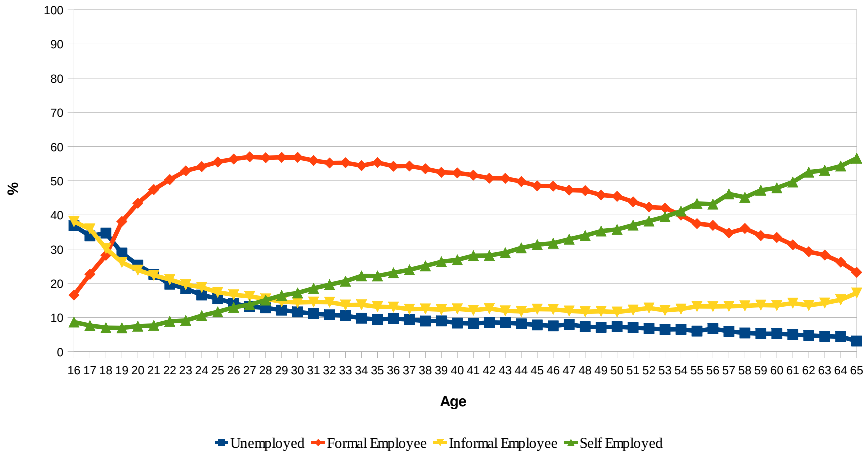
	Self Employed	Informal Wage Earners	Formal Wage Earners	Unemployed
Age (mean)	40.2	31.1	33.7	28.7
Schooling (% by group)				
<9	63.2	55.4	40.1	50.5
10-11	24.4	30.8	40.7	40.5
12+	12.4	13.7	19.2	9.0
% Males	63.9	63.8	60.8	47.5
Labour Income (mean)	$841	$666	$1066	-
Labour Income (std.dev.)	$1016	$800	$1146	-
Labour Income (# obs)	120,465	92,057	291,664	
% Who Contribute to Social Security	15.4	11.8	99.5	-
% Who Work Full-time (35+ weekly hours)	74.1	81.0	92.7	-
Firm size - # workers (%)				
1 (owner-only)	82.2	-	-	-
2-5	15.8	38.0	6.0	-
6-10	0.5	11.7	6.3	-
11+	1.4	50.3	87.7	-
Occupation-skill (%)				
Production, Maintenance & Repair	33.8	28.3	25.0	-
Sales	22.3	7.3	6.7	-
Agriculture & Extraction	20.4	20.5	3.9	-
Services	11.5	15.6	18.6	-
Other (skilled occupations)*	12.0	28.3	45.8	-

Note: The sample includes all individuals between ages 16 and 65. The variable indicating payroll contributions is obtained from PNAD 2002-2007 using a sample of 1,186,853 workers. All other variables are constructed using a sample of 700,686 individuals from PME 2002-2007. Income values are gross per month and expressed in Reais of 2008 [1 US dollar equals 1.83 Real in 2008].

* Professionals, Administrative, Management, Technicians with High School, Military.

FIGURE 1

Composition of workforce by Age, Brazil, 2002-2007



Note: Brazilian Labor Force Survey 2002-2007. The sample includes 700,686 individuals. Figure is constructed using individuals' employment status at the date of their first interview.

TABLE 2

Monthly Transitions, PME, 2002-2007

	Age (Years)				
	16-25	26-35	36-45	46-55	56-65
Transitions into Self Employment from (% of individuals by initial status)					
Unemployment	3.18	7.22	10.60	12.66	14.81
Formal Employment (as wage earner)	0.05	0.05	0.05	0.05	0.02
Informal Employment (as wage earner)	0.20	0.34	0.47	0.41	0.42
Transitions from Self Employment to (% of individuals by initial status)					
Unemployment	5.45	3.17	2.33	1.69	1.20
Formal Employment (as wage earner)	0.33	0.27	0.20	0.08	0.06
Informal Employment (as wage earner)	1.44	0.77	0.52	0.29	0.26

Note: Brazilian Labor Force Survey 2002-2007, based on a sample of 700,686 individuals. Transitions are per month, starting from the individuals' first interview. They show percentages of individuals by initial status who moved to other statuses, as the rows indicate.

than wages of younger (older) informal employees. Remarkably, the gap between formal and self employment incomes increases as workers get older. Thus, labour incomes alone do not seem to explain why self employment increases with age, on one hand, and formal employment decreases, on the other.

TABLE 3

Log of Take Home Income per Month, PME 2002-2007

	Age (Years)				
	16-25	26-35	36-45	46-55	56-65
Formal Sector Wage					
Mean	6.36	6.62	6.72	6.79	6.74
Std. Dev.	0.45	0.59	0.65	0.68	0.69
# Obs.	73,957	100,340	71,691	36,420	9,256
Informal Sector Wage					
Mean	6.02	6.29	6.35	6.42	6.43
Std. Dev.	0.52	0.67	0.73	0.78	0.8
# Obs.	36,026	25,378	16,795	9,845	4,013
Self Employed Income					
Mean	6.08	6.34	6.39	6.41	6.34
Std. Dev.	0.72	0.82	0.83	0.86	0.89
# Obs.	12,595	29,592	36,115	28,882	13,281

Note: Brazilian Labor Force Survey 2002-2007, based on a sample of 700,686 individuals. Numbers are the logarithm of monthly incomes in Reais of 2008 net of payroll contributions and income tax.

In table 4, I report regression estimates of the relationship between age and transitions into self employment, controlling for main observables. I use two different specifications, one which looks at transitions from unemployment which is the most frequent and another which analyses transitions from being wage earners. In the last specification, I add a control for formal or informal sectors, and I consider the wage level prior moving into self employment.

In column 1 of table 4, the coefficient on age is positive and statistically significant, indicating that the unemployed are more likely to become self employed as they get older. The coefficient on age squared is negative and jointly significant with the coefficient on age, suggesting that the relationship between age and entry from unemployment to self employment is non linear. However, because the coefficient on age squared is very small, the entry probability never decreases with age over the range considered 16-65. The average age of the unemployed is 28.7 years, for every three additional years of age there is an average increment of one percent in the probability that the unemployed become self employed. Given that the probability of those unemployed becoming self employed is on average 6.2, this change is significantly large.

Now, looking at column 2 of table 4, age is much less important in determining entry into self employment from being wage earners. Not surprisingly, this is due to much fewer transitions taking place in this direction. On average, only 0.1 percent of wage earners move into self employment. The coefficient on age is positive and statistically significant, suggesting positive but weak correlation between age and entry of wage earners into self employment. In general, these regressions show that prior wage level, work as wage earner in the formal sector, females, and having high education seem associated with relatively low self employment entry.

All this evidence together suggest that self employment and informal wage sector are important categories of employment. All else equal, we observe a strong empirical relationship between age and entry into self employment, mainly from unemployment. Labour incomes alone do not seem to explain why self employment rates increase so steeply with individual's age. These are facts which I seek to account for in the next sections of the paper.

TABLE 4

Linear Probability Model Estimates of Self Employment Entry

	[1] From Unemployment	[2] From Being Wage Earners
Age	0.006	0.000134
	[0.001]	[0.000036]
Age squared	-0.000046	-0.0000016
	[.000011]	[0.0000005]
Dummy Males	0.036	0.00074
	[0.002]	[0.00010]
Dummy Education 10-11	-0.029	-0.00043
	[0.002]	[0.00012]
Dummy Education 12+	-0.039	-0.00023
	[0.003]	[0.00016]
Wage level/$1,000	-	-0.00015
		[0.00004]
Dummy Informal wage earner	-	0.00218
		[0.00021]
Additional controls	yes	yes
Observations	52,474	289,427
R-squared	0.052	0.001
p-value of joint significance of age and age squared variables	0.000	0.000

Note: This table reports linear probability model estimates of the transition into self employment in the month subsequent to the first interview. I use a sample of individuals initially unemployed or wage earners, using the Brazilian Labour Force Surveys 2002-2007. Column 1 reports estimates using transitions from unemployment and column 2 from being wage earners. Regressions include controls for year and region. The excluded dummies are females, less than 9 years of education, and formal wage earner. The sample mean of the proportion of workers who enter into self employment from unemployment is 0.062, and from being wage earners 0.001. Robust standard errors are reported in parentheses.

2 The Framework

Consider a worker with potential work experience ε (age *minus* completed schooling *minus* statutory age of entry at school). Time is discrete, thus ε is an integer and belongs to $\{1,...,E\}$ where E is exogenous, determined by the age of retirement. At time t, the individual can be unemployed, work for a firm in the formal sector, work for a firm in the informal sector or can be self employed.

The transitions across employment statuses are modelled as follows. There is a finite-state Markov chain with conditional transition probabilities given by $Pr\{s_{\varepsilon+1,t+1} = s\prime | s_{\varepsilon,t} = s\}$, where s and $s\prime$ belong to {0 (unemployed),1 (formal employee),2 (informal employee),3 (self employed)}. A worker who is employed in sector $i \in \{1,2,3\}$ at the beginning of period t faces a probability $\delta^{i}_{\varepsilon,t}$ of becoming unemployed. While unemployed, an individual has a probability $\lambda^{0i}_{\varepsilon,t}$ of getting a job offer in one of the sectors of employment i. An individual who remains employed searches while on the job and, with probability $\lambda^{ij}_{\varepsilon,t}$, moves from a job in sector i to j, where $i \in \{1,2,3\}$ and $j \in \{1,2\}$. Hence, all workers search while on the job and can be offered another job with a formal or an informal firm.[9]

In this regard, I assume that a worker can only move into self employment from unemployment and not from searching on the job.[10] The parameter $\lambda^{03}_{\varepsilon,t}$ is the probability of entry into self employment from unemployment. The dependence of this probability on the worker's potential experience formalises the hypothesis that entry into self employment is frictional *in the sense that* it takes work experience for individuals to learn about good business opportunities to undertake.

These parameters and the remaining objects of the model will be allowed to vary with exogenous variables such as education and gender. However, to simplify the notation, I present the model considering that mobility and other variables of the model only depend on the worker's potential experience, changing deterministically overtime.

While a job remunerates an employee at w per period, which is drawn from distributions of wage offers, an unemployed individual enjoys a non-labour income of $b_{\varepsilon,t}$, and a self employed worker earns a deterministic labour income of $\pi_{\varepsilon,t}$ per period and for each experience level.

Wage offers are random draws from $F^{i}(w)$ which is can differ across sectors of employment, formal and informal ($i = 1,2$). Define $\overline{F}^{i}(w) = 1 - F^{i}(w)$ the probability that a wage offer in sector i is higher than w.[11]

Let $U_{\varepsilon,t}$ denote the present value of unemployment in period t for a worker with experience ε. $W^{1}_{\varepsilon,t}(w)$ and $W^{2}_{\varepsilon,t}(w)$ represent the values of a job which pays w in formal firms and of a job which pays the same in informal firms, respectively. Finally, let $W^{3}_{\varepsilon,t}$ be the present value of self employment.

To obtain the lifetime values of individuals in each state, one needs knowledge on the model's structural parameters in the future, i.e. we need to know what $\delta^{i}_{\varepsilon,t}$, $\lambda^{0i}_{\varepsilon,t}$, $\lambda^{ij}_{\varepsilon,t}$, and $b_{\varepsilon,t}$ will be in the future. I assume rational expectations and that the individuals' best guess about these parameters in the future $(t+1, t+2, ...)$ is the value of these parameters for older workers in time t. Under this particular assumption using rational expectations, the future value of a worker in each status $U_{\varepsilon+1,t+1}$ and $W^{i}_{\varepsilon+1,t+1}$, for $i \in \{1,2,3\}$, is replaced by $U_{\varepsilon+1,t}$ and $W^{i}_{\varepsilon+1,t}$, respectively. That is, a worker with experience ε uses the mobility rates which a worker with one more year of experience $(\varepsilon+1)$ faces today to predict his own mobility one year later from today. With this assumption, the only non-stationarity which remains comes from the ageing process.[12] Given that parameter and variables of the model vary with potential work experience but not with time, *I omit time in the notation from now on.*

[9]These event probabilities already account for the probability that the individuals die at any age or conditional on employment status. This shall become clear in the estimation section. I will estimate these probabilities by fitting the observed transitions in data.

[10]The labour force data shows that the relevant transitions into self employment are from unemployment.

[11]That wage offers distributions do not vary by work experience is an assumption which will become clear in subsection 2.2.

[12]This particular assumption using rational expectations makes the problem more tractable but also appears to be a good approximation of individuals's true expectation process. It is supported by US data which shows that transition rates exhibit characteristics of random walks [see, for example, Bowlus and Robin (2004)].

Before proceeding with the Bellman equations, I will first define the optimal strategies of the workers. Since $W_\varepsilon^1(w)$ and $W_\varepsilon^2(w)$ are increasing in w,[13] there exists a reservation wage for offers arriving from the formal sector $R_{\varepsilon+1}^{01}$ and one for offers from the informal one $R_{\varepsilon+1}^{02}$, such that workers are indifferent between accepting a job offer and remaining unemployed:

$$U_\varepsilon = W_\varepsilon^1(R_{\varepsilon+1}^{01}) = W_\varepsilon^2(R_{\varepsilon+1}^{02});$$

For the same reason, there exists a reservation wage for offers arriving from the formal sector $R_{\varepsilon+1}^{31}$ and one for offers from the informal one $R_{\varepsilon+1}^{32}$, such that workers are indifferent between accepting a job offer and remaining self employed:

$$W_\varepsilon^3 = W_\varepsilon^1(R_{\varepsilon+1}^{31}) = W_\varepsilon^2(R_{\varepsilon+1}^{32});$$

Now, because there is a distribution of wages in the formal and in the informal sectors, there exists a reservation wage function which depends on the workers' current wage in each sector; $R_{\varepsilon+1}^{12}(w)$ is the reservation wage which makes workers earning at w indifferent between accepting a job offer as wage earners in the informal sector and remain in the formal sector:

$$W_\varepsilon^2(R_{\varepsilon+1}^{12}(w)) = W_\varepsilon^1(w);$$

This similarly applies to workers originally in the informal sector earning at w; there exists a reservation wage function $R_{\varepsilon+1}^{21}(w)$ which makes workers earning at w indifferent between accepting a job offer as wage earners in the formal sector and remain in the informal sector:

$$W_\varepsilon^1(R_{\varepsilon+1}^{21}(w)) = W_\varepsilon^2(w).$$

The reservation wage of workers to accept a job within the same sector are their current wage.

By these assumptions, the Bellman equations for the individuals in each working status are:

- unemployed

$$\begin{aligned}(1+r)U_\varepsilon &= b_\varepsilon + \lambda_\varepsilon^{01}\int_{R_{\varepsilon+1}^{01}}^{\overline{w}^1} W_{\varepsilon+1}^1(x)dF^1(x) + \lambda_\varepsilon^{02}\int_{R_{\varepsilon+1}^{02}}^{\overline{w}^2} W_{\varepsilon+1}^2(x)dF^2(x) \\ &\quad + \lambda_\varepsilon^{03}\max\{W_{\varepsilon+1}^3, U_{\varepsilon+1}\} + [1-d_\varepsilon^0]U_{\varepsilon+1};\end{aligned} \tag{1}$$

where $d_\varepsilon^0 = \lambda_\varepsilon^{01}\overline{F}^1(R_{\varepsilon+1}^{01}) + \lambda_\varepsilon^{02}\overline{F}^2(R_{\varepsilon+1}^{02}) + \lambda_\varepsilon^{03}1(W_{\varepsilon+1}^3 > U_{\varepsilon+1})$ is the probability of an individual with experience ε to leave unemployment and $1(\cdot)$ is an indicator function equal to 1 if the argument is true, 0 otherwise. The unemployed enjoy the non-labour income of b_ε at each instant plus the expected continuation value.

- self employed

$$\begin{aligned}(1+r)W_\varepsilon^3 &= \pi_\varepsilon + \delta_\varepsilon^3 U_{\varepsilon+1} + \lambda_\varepsilon^{31}\int_{R_{\varepsilon+1}^{31}}^{\overline{w}^1} W_{\varepsilon+1}^1(x)dF^1(x) \\ &\quad + \lambda_\varepsilon^{32}\int_{R_{\varepsilon+1}^{32}}^{\overline{w}^2} W_{\varepsilon+1}^2(x)dF^2(x) + [1-d_\varepsilon^3]W_{\varepsilon+1}^3;\end{aligned} \tag{2}$$

[13] It can be showed next by deriving the workers' value functions with respect to w, that $W_\varepsilon^{1\prime}(w)$ and $W_\varepsilon^{2\prime}(w)$ are positive. Because at the end of life $W_E^{1\prime}(w)$ and $W_E^{2\prime}(w)$ are positive, solving backwards show that $W_\varepsilon^{1\prime}(w)$ and $W_\varepsilon^{2\prime}(w)$ are also positive for all ε.

where $d_\varepsilon^3 = \delta_\varepsilon^3 + \lambda_\varepsilon^{31}\overline{F}^1(R_{\varepsilon+1}^{31}) + \lambda_\varepsilon^{32}\overline{F}^2(R_{\varepsilon+1}^{32})$ is the probability of separating from self employment, given experience ε. Conditional on having an offer from a firm in sector i, self employed workers with experience ε leave their jobs with probability $\overline{F}^i(R_{\varepsilon+1}^{3i})$. Self employed incomes vary deterministically with experience and, later in the estimation, will be also allowed to vary with sex and education.

In the formal sector, the flow value includes the worker's gross wage, w, the payments towards his severance account $s \times w$ and the unemployment insurance (UI) in the case of layoff. For simplicity, I assume UI is paid upfront as compensation when the worker is laid off and does not depend on the worker's experience. While severance pay is financed by the firm, UI is funded by labour taxation by imposing a government budget constraint which I explain later in the estimation section.

- formal employee

$$\begin{aligned}(1+r)W_\varepsilon^1(w) &= w + \delta_\varepsilon^1(U_{\varepsilon+1} + UI + sw) + \lambda_\varepsilon^{11}\int_w^{\overline{w}^1} W_{\varepsilon+1}^1(x)dF^1(x) \\ &\quad + \lambda_\varepsilon^{12}\int_{R_{\varepsilon+1}^{12}(w)}^{\overline{w}^2} W_{\varepsilon+1}^2(x)dF^2(x) + [1-d_\varepsilon^1(w)]W_{\varepsilon+1}^1(w);\end{aligned} \tag{3}$$

with $d_\varepsilon^1(w) = \delta_\varepsilon^1 + \lambda_\varepsilon^{11}\overline{F}^1(w) + \lambda_\varepsilon^{12}\overline{F}^2(R_{\varepsilon+1}^{12}(w))$ being the probability of separating from a job as wage earner valued at w, in the formal sector.

- informal employee

$$\begin{aligned}(1+r)W_\varepsilon^2(w) &= w + \delta_\varepsilon^2 U_{\varepsilon+1} + \lambda_\varepsilon^{22}\int_w^{\overline{w}^2} W_{\varepsilon+1}^2(x)dF^2(x) \\ &\quad + \lambda_\varepsilon^{21}\int_{R_{\varepsilon+1}^{21}(w)}^{\overline{w}^1} W_{\varepsilon+1}^1(x)dF^1(x) + [1-d_\varepsilon^2(w)]W_{\varepsilon+1}^2(w).\end{aligned} \tag{4}$$

with $d_\varepsilon^2(w) = \delta_\varepsilon^2 + \lambda_\varepsilon^{21}\overline{F}^1(R_{\varepsilon+1}^{21}(w)) + \lambda_\varepsilon^{22}\overline{F}^2(w)$ being the probability of separating from a job as wage earner valued at w, in the informal sector.

In the above equations, I assume that employers have enough monopsony power to force minimum wages paid in each sector such that $W_\varepsilon^i(\underline{w}_\varepsilon^i) = U_\varepsilon$. In particular, this condition is used for informal sector firms, which are not restricted by minimum wage laws. This will enable identification of non-labour income b_ε.

Equations (1) through (4) provide a set of recursive equations which can be solved by backward induction. At the end of working lifetime, I set $U_{E+1} = W_{E+1}^i = 0$, for $i \in \{1,2,3\}$. This is a normalisation which follows from model assumptions such as linear utility, time preference discount rate is equal to the interest rate and that retirement income results only from history of the individual in the labour market, i.e. which are already accounted for in the gross labour incomes. The last assumption is the reason why the instant value of a worker in any sector of employment needs to be gross income (*before* pension contribution but *after* income tax) instead of take-home pay.

2.1 Employment Composition Over the Life Cycle

The measure of workers with experience ε is normalised to one, so that the proportion of individuals in each sector is m_ε^i and the fraction of unemployed u_ε $(= 1 - m_\varepsilon^1 - m_\varepsilon^2 - m_\varepsilon^3)$. Let $M_\varepsilon^i(w) = m_\varepsilon^i G_\varepsilon^i(w)$ for $i = 1,2$ be the measure of workers in sector i, with experience ε which earn a current wage less than w. Then, define the life cycle evolution of employment in each sector i,

- self employed

$$m^3_{\varepsilon+1} = [1-d^3_\varepsilon]m^3_\varepsilon + \lambda^{03}_\varepsilon u_\varepsilon 1(W^3_{\varepsilon+1} > U_{\varepsilon+1}); \tag{5}$$

  where $d^3_\varepsilon = \delta^3_\varepsilon + \lambda^{31}_\varepsilon \overline{F}^1(R^{31}_{\varepsilon+1}) + \lambda^{32}_\varepsilon \overline{F}^2(R^{32}_{\varepsilon+1})$ is the probability that a worker with experience ε separates from self employment.

The number of self employed with experience $\varepsilon+1$ is equal to the number of self employed with experience ε who did not move out of self employment *plus* the formerly unemployed who found atractive the opportunity of moving into self employment.

- formal employee

$$\begin{aligned} M^1_{\varepsilon+1}(w) &= [1-d^1_\varepsilon(w)]M^1_\varepsilon(w) + \lambda^{01}_\varepsilon u_\varepsilon \left[F^1(w) - F^1(R^{01}_{\varepsilon+1})\right] \\ &\quad + \lambda^{21}_\varepsilon \int_{\underline{w}^2}^{\overline{w}^2} [F^1(w) - F^1(R^{21}_{\varepsilon+1}(x))] dM^2_\varepsilon(x) \\ &\quad + \lambda^{31}_\varepsilon m^3_\varepsilon [F^1(w) - F^1(R^{31}_{\varepsilon+1})] 1(w > R^{31}_{\varepsilon+1}); \end{aligned} \tag{6}$$

  where $d^1_\varepsilon(w) = \delta^1_\varepsilon + \lambda^{11}_\varepsilon \overline{F}^1(w) + \lambda^{12}_\varepsilon \overline{F}^2(R^{12}_{\varepsilon+1}(w))$ is the probability of separating from a job as wage earner valued at w, in the formal sector.

- informal employee

$$\begin{aligned} M^2_{\varepsilon+1}(w) &= [1-d^2_\varepsilon(w)]M^2_\varepsilon(w) + \lambda^{02}_\varepsilon u_\varepsilon \left[F^2(w) - F^2(R^{02}_{\varepsilon+1})\right] \\ &\quad + \lambda^{12}_\varepsilon \int_{\underline{w}^1}^{\overline{w}^1} [F^2(w) - F^2(R^{12}_{\varepsilon+1}(x))] dM^1_\varepsilon(x) \\ &\quad + \lambda^{32}_\varepsilon m^3_\varepsilon [F^2(w) - F^2(R^{32}_{\varepsilon+1})] 1(w > R^{32}_{\varepsilon+1}). \end{aligned} \tag{7}$$

  where $d^2_\varepsilon(w) = \delta^2_\varepsilon + \lambda^{21}_\varepsilon \overline{F}^1(R^{21}_{\varepsilon+1}(w)) + \lambda^{22}_\varepsilon \overline{F}^2(w)$ is the probability of separating from a job as wage earner valued at w, in the informal sector.

That is, the total number of workers in state i $(=1,2)$, with experience $\varepsilon+1$, is equal to the number of workers in state i a period earlier (i.e. with experience ε) who did not move *plus* the number of formerly unemployed workers who found a job in state i (paying less than w) *plus* the formerly employed workers from other sectors of employment who accepted a wage up to w.

The equations above describe the law of motion of the measure of formal sector workers $M^1_\varepsilon(w)$, the measure of informal sector workers $M^2_\varepsilon(w)$, the measure of self employed m^3_ε and the measure of unemployed u_ε $(= 1 - M^1_\varepsilon(\overline{w}) - M^2_\varepsilon(\overline{w}) - m^3_\varepsilon)$.

2.2 Firms and Equilibrium

In this model, firms are ex-ante heterogeneous and have a productivity p following Bontemps, Robin and Van den Berg (2000). They can be either formal or informal in terms of compliance with business, labour taxes and minimum wages. In the formal sector, the distribution function of p is $\Gamma^1(p)$ and in the informal sector $\Gamma^2(p)$, with possible different supports which I denote by $[\underline{p}^i, \overline{p}^i]$. $\Gamma^i(p)$ is continuous. The measure of firms is one, n_1 is the proportion of formal firms hence $n_2 = 1 - n_1$ is the proportion of informal firms, which is exogenous.[14]

[14] I use the estimated proportion of formal firms (n_1) obtained in Meghir, Narita and Robin (2010) for similar sample of workers.

I assume firms cannot assess the experience of the worker and that they pay equal wages, w, across different levels of experience.[15] Firms enter the market *as long as w is greater than at least one reservation wage*, i.e. $w \geq \min\{R_1^{0i}, R_2^{0i}, ..., R_E^{0i}\}$ in sector i. Otherwise, offering lower than $\min\{R_1^{0i}, R_2^{0i}, ..., R_E^{0i}\}$ implies the firm attracts no workers.

In the formal sector, firms have to pay payroll taxes (τ), corporate taxes on profits (σ) and severance payments in proportion to the current wage ($s \times w$) to workers who are laid off. These firms are also subject to minimum wage laws ($w_{\min}$). This adds an additional restriction on the wages offered in the formal sector and, more generally, it becomes $w \geq \max\left\{w_{\min}, \min\{R_1^{0i}, R_2^{0i}, ..., R_E^{0i}\}\right\}$. Informal labour markets are monitored by the government authorities, whose role is to enforce tax and labour laws. Firms operating unofficially do not pay any form of taxes but are subject to a cost C equal to the probability of being caught by the labour authorities multiplied by a fine, which is here assumed fixed per worker.[16]

To keep the model as simple as possible only the steady-states are considered. Following Burdett and Mortensen (1998), the unemployed who receive acceptable offers become employed. Those already employed seek a better job (which delivers a higher value, *not necessarily a higher wage*) and take it when it is found. Hence, employers set wage policies to attract workers as well as to retain existing employees. The wage policy is assumed constant throughout the tenure of the match.[17]

In steady-state, profit equals the measure of employed workers per firm multiplied by the profit per worker. Because firms cannot assess workers' experience, their profits are a weighted average of their profits at different levels of experience using the density of potential experience γ_ε.

Given $F^1(w)$ and $F^2(w)$, the steady state profit of a firm with productivity p in the formal sector is

$$\pi_1(p,w) = (1-\sigma)\sum_{\varepsilon}[p - (1+\tau+\delta_\varepsilon^1 s)w]\ell_\varepsilon^1(w)\gamma_\varepsilon; \tag{8}$$

In the informal sector, the steady state profit of a similar firm is

$$\pi_2(p,w) = [p - w - C]\sum_{\varepsilon}\ell_\varepsilon^2(w)\gamma_\varepsilon; \tag{9}$$

where $\ell_\varepsilon^i(w)$ is the measure of workers per firm (firm size) which is expected given the workers' reservation wage strategies and that wages offered by other firms follow the distribution F^i.

Using the law of motion in (6) and (7), the measure of workers with experience ε earning at w in sector 1 and 2 are, respectively, $dM_\varepsilon^1(w)$ and $dM_\varepsilon^2(w)$. I assume firms offer only *one* wage and that all firms post wages such that $n_1 dF^1(w)$ is the measure of formal firms and $n_2 dF^2(w)$ the measure of informal firms offering a wage equal to w. Hence, the labour force size of firms paying at w in each sector are:

$$\begin{aligned} \ell_\varepsilon^1(w) &= \frac{1}{n_1}\frac{dM_\varepsilon^1(w)}{dF^1(w)}; \\ \ell_\varepsilon^1(w) &= \frac{1}{n_2}\frac{dM_\varepsilon^2(w)}{dF^2(w)}. \end{aligned}$$

Firms in each sector, given p, then choose a monopsonistic wage w to maximise their steady state profit $\pi_i(p,w)$, which takes into account that workers are welfare maximizers and that all other firms offer wages that are distributed according to F^i. Moreover, a firm with productivity p in the informal sector does not offer a wage greater than $p - C$, otherwise profits would be negative. In the formal sector, however, due to expected firing costs which vary by work experience, it could be that firms in that sector make negative

[15] A suggestion for future research is to allow for offered wages to vary by work experience.

[16] This cost parameter will be estimated using data on number of inspections per firm and the value of fines due to lack of workers' registration. Because available data on inspections varies per region and not by type of firm (according to size or productivity) and because fines of that type are fixed per worker, the estimate of the cost of informality will be fixed per worker. Meghir, Narita and Robin (2010), use the model to recover the cost of informality and allow it to vary with firm size.

[17] Burdett and Coles (2003) extend Burdett and Mortensen (1998) to allow for wage-tenure contracts.

profits (per worker) for hiring *some* workers, i.e. by offering a wage above $p/(1+\tau+\delta_\varepsilon^1 s)$. For example, this may happen when size ($\ell_\varepsilon^1(w)$) is small and the job destruction probability (δ_ε^1) is high. In compensation, by offering such a wage, firms attract many more workers at other levels of experience which are likely to become employed ($\ell_\varepsilon^1(w)$ high) and to remain employed (δ_ε^1 is small).

Now, I proceed with the definition of market equilibrium. The equilibrium concept used here follows that in Bontemps, Robin and Van den Berg (2000). Equilibrium in the labour market is characterised by the workers' reservation wages (R_ε^{01}, R_ε^{02}, R_ε^{31}, R_ε^{32}, $R_\varepsilon^{12}(w)$, $R_\varepsilon^{21}(w)$), the condition for entry into self employment ($W_\varepsilon^3 > U_\varepsilon$), the measure of workers by state over the life cycle ($M_\varepsilon^1(w), M_\varepsilon^2(w), m_\varepsilon^3$), and by the distribution of wage offers ($F^1(w), F^2(w)$) such that

1. Using equations (1)-(4), R_ε^{0i} solve $W_\varepsilon^i(R_\varepsilon^{0i}) = U_\varepsilon$, R_ε^{3i} solve $W_\varepsilon^i(R_\varepsilon^{3i}) = W_\varepsilon^3$, $R_\varepsilon^{ij}(w)$ solve $W_\varepsilon^j(R_\varepsilon^{ij}(w)) = W_\varepsilon^i(w)$ (i,j=1,2), given the distributions of wage offers $F^1(w)$ and $F^2(w)$

2. The measure of workers $M_\varepsilon^1(w), M_\varepsilon^2(w)$ and m_ε^3 are consistent with dynamics of employment in each state (equations (5) through (7)) given the distributions of wage offers $F^1(w)$ and $F^2(w)$ and the worker reservation wages;

3. Each type p firm chooses a wage policy $K^i(p)$ in the set $\Omega^i(p)$ which maximises its steady-state profits given that other firms draw wage offers from $F^i(w)$ and workers' reservation wage strategies

Denote by $\Omega^i(p)$ the set from which firms by type in each sector i select their profit maximizing wages.

$$\Omega^1(p) = \left\{w; \max\left\{p/(1+\tau+\delta_1^1 s), ..., p/(1+\tau+\delta_E^1 s)\right\} \geq \mathrm{w} \geq \max\left\{w_{\min}, \min\{R_1^{01}, R_2^{01}, ..., R_E^{01}\}\right\}\ \right\};$$

and

$$\Omega^2(p) = \left\{w; p - C \geq w \geq \min\{R_1^{02}, R_2^{02}, ..., R_E^{02}\}\right\}.$$

Thus the optimal wage paid by a firm of productivity p is

$$\begin{aligned} K^1(p) &= \arg\max_{w\in\Omega^1(p)} \{\pi_1(p,w)|F^1(w), F^2(w)\}; \\ K^2(p) &= \arg\max_{w\in\Omega^2(p)} \{\pi_2(p,w)|F^1(w), F^2(w)\}. \end{aligned}$$

where $\pi_i(p,w)$ is defined by the functions (8) and (9).

The proof of equilibrium is analogous to the one in Bontemps, Robin and Van den Berg (2000). Only one wage can be profit maximising for a firm of a given type. This follows from the fact that there is a continuous distribution of firms' types. Also, observe that in equilibrium $p = K^{i^{-1}}(w)$ and because $K^i(p)$ is increasing in p, it follows that the distribution of chosen wages by the firm is equal to the productivity distribution $F^i(w) = \Gamma^i(p)$.[18]

The distribution of productivities $\Gamma^i(p)$ is thus the key determinant of the offers distribution. It allows solving for the remaining objects of the model. The next step is to show how equilibrium wages are solved for. Assume $\Gamma^i(p)$ is known, by the envelope theorem

$$\begin{aligned} \frac{d\pi_1(p,w)}{dp} &= \frac{\partial \pi_1(p,w)}{\partial p}|_{w=K^1(p)} = (1-\sigma)\sum_\varepsilon \ell_\varepsilon^1(K^1(p))\gamma_\varepsilon; \\ \frac{d\pi_2(p,w)}{dp} &= \frac{\partial \pi_2(p,w)}{\partial p}|_{w=K^2(p)} = \sum_\varepsilon \ell_\varepsilon^2(K^2(p))\gamma_\varepsilon. \end{aligned}$$

[18] Using the second order condition of the firms' problem, wage policies conditional on employer productivity must be increasing functions of the productivity parameter.

which imply

$$\pi_1(p) = \pi_1(\underline{p}) + (1-\sigma)\int_{\underline{p}}^{p} \sum_{\varepsilon} \ell_{\varepsilon}^{1}(K^1(x))\gamma_{\varepsilon}dx; \tag{10}$$

$$\pi_2(p) = \pi_2(\underline{p}) + \int_{\underline{p}}^{p} \sum_{\varepsilon} \ell_{\varepsilon}^{2}(K^2(x))\gamma_{\varepsilon}dx. \tag{11}$$

By equating (8) to (10), equilibrium wages in the formal sector by productivity are given by

$$\begin{aligned} K_1(p) = {} & p\frac{\sum_{\varepsilon}\ell_{\varepsilon}^{1}(K^1(p))\gamma_{\varepsilon}}{\sum_{\varepsilon}(1+\tau+\delta_{\varepsilon}^{1}s)\ell_{\varepsilon}^{1}(K^1(p))\gamma_{\varepsilon}} \\ & -\frac{1}{\sum_{\varepsilon}(1+\tau+\delta_{\varepsilon}^{1}s)\ell_{\varepsilon}^{1}(K^1(p))\gamma_{\varepsilon}}\left(\frac{1}{(1-\sigma)}\pi_1(\underline{p}^1) + \int_{\underline{p}}^{p}\sum_{\varepsilon}\ell_{\varepsilon}^{1}(K^1(x))\gamma_{\varepsilon}dx\right); \end{aligned}$$

and, by equating (9) to (11), it follows the equilibrium wages in the informal sector

$$K_2(p) = p - C - \frac{1}{\sum_{\varepsilon}\ell_{\varepsilon}^{2}(K^2(p))\gamma_{\varepsilon}}\left(\pi_2(\underline{p}^2) + \int_{\underline{p}}^{p}\sum_{\varepsilon}\ell_{\varepsilon}^{2}(K^2(x))\gamma_{\varepsilon}dx\right).$$

Because $\underline{p}^i$ defines the level of productivity below which firms in each sector are inactive, $\pi_1(\underline{p}^1) = \pi_2(\underline{p}^2) = 0$.

The above equations show that wages in equilibrium are a fraction of workers' productivity. Taxes on the formal sector firms and penalty cost for operating informally tend to reduce wages. Labour market frictions faced by all workers who search for a job with a firm (including the self employed) determine the extent to which firms can exploit their monopsony power. It is possible to show that more frictions (lower probability of getting a job with a firm) increase the terms $\pi_1(p)/\sum_{\varepsilon}(1+\tau+\delta_{\varepsilon}^{1}s)\ell_{\varepsilon}^{1}(K^1(p))\gamma_{\varepsilon}$ and $\pi_2(p)/\sum_{\varepsilon}\ell_{\varepsilon}^{2}(K^2(p))\gamma_{\varepsilon}$ which appear on the right hand side of equilibrium wage equations. Consequently, reducing wages in relation to firms' productivity. It is also possible to show that when there is no on the job search ($\lambda_{\varepsilon}^{ij} = 0;\, i = 1,2,3\, and\, j = 1,2$) labour force sizes are constant. Firms in this case do not attract more workers by offering higher wages. Thus, they will set wages at the lowest level to attract at least some workers, for example a wage in $\{R_1^{02}, R_2^{02}, ..., R_E^{02}\}$ which does not exceed $p - C$ in sector 2. This is the extreme case in which firms enjoy maximum monopsony power, also known as the Diamond (1971)'s solution.

One case of particular interest in this paper is how self employment affects wages in the formal and informal sector. The above analysis shows that if the self employed receive offers from firms in the formal and informal sectors (i.e. if $\lambda_{\varepsilon}^{31} > 0$ and $\lambda_{\varepsilon}^{32} > 0$), the extent of these offers and their willingness to take a job as wage earners affect labour force size, hence wages in both sectors.

3 The Labour Force Data

The main source of data consists of a panel of individuals sampled by the labour force survey of Brazil, *Pesquisa Mensal de Emprego* (PME). PME was designed and conducted by the National Statistics Bureau to follow individuals in the six largest metropolitan regions of Brazil. It has similar structure as that of the CPS (Current Population Survey). Individuals are interviewed during four consecutive months, then for another four consecutive months one year after their entry into the sample. The sample period I use starts on January 2002 and runs until December 2007.

This paper uses a sample of 700,686 individuals, aged 16 to 65, who are found to be either unemployed, self employed or working as an employee (registered or unregistered). The definition of formal workers in this paper is whether the worker's current job is registered with the Ministry of Labour.[19] [20]

In this paper, I follow individuals over two periods. I locate them in their first interview and then follow them for a month. During the period of analysis, which is a month, the possible transitions can be job-to-job, unemployment-to-job or job-unemployment, where the job can be as self employed, as an employee in the formal or as an employee in the informal sector.[21] At the date of the first interview, I observe the worker's employment status, the wage earned or the income of self employment. From the following month, I use the worker's employment status to construct the transition indicators. What allows identification of transitions within sector (i.e. formal to formal and informal to informal) is the survey question about length of job spell.[22]

To account for observed workers' heterogeneity, I assume markets can be segmented by sex and education. I separate the sample by sex and three groups of education and I estimate the model for each of those six markets.[23] I divide the education categories into up to and including 9 years of schooling, 10 and 11 years of schooling, and 12 or more years of schooling. Within each subgroup of workers by sex and education, work experience varies. Potential work experience is computed as age minus years of education minus 7 (which is the statutory age of entry in school in Brazil for the cohorts used in this study). Then, this variable is categorised as follows: 0-5, 6-10, 11-15, 16-20, 21-29, 30-39, and 40 and above years.

A complete description of the stock of workers per employment status and of the transition data by education and experience group is summarised in Tables 7 to 9 in the Appendix. I have pooled some work experience groups just for the results to fit in these particular tables, however estimates below are obtained for each of the above mentioned seven groups. All the transitions are per month and data is pooled across all months of PME between 01/2002 and 12/2007. In particular these tables show averages, by subsample, of the proportion of unemployed workers who move from unemployment to job (D_{ε}^{0j}; $j = 1,2,3$), the proportion of formal employees who move to unemployment, to another job in the same sector or to the informal sector (D_{ε}^{1j}; $j = 0,1,2$), similar ones for employees initially in the informal sector ($D_{\varepsilon}^{2j}; j = 0,1,2$) and the proportion of self employed who become unemployed, formal or informal wage earners (D_{ε}^{3j}; $j = 0,1,2$). Notice that these tables report the transitions from a formal or an informal job with firms to self employment, however because these are the least important mobilities among wage earners, I ignore these transitions in the model.

Now, I describe how labour incomes are treated in this study. In Brazil, there is a federal minimum wage, which should be the minimum paid to all formal employees, that is, workers in other sectors of employment (informal employment with a firm and self employment) may earn less than the legal minimum. The average legal minimum wage over the sample period is of 300 Reais per month.[24] Workers under a formal contract found to earn less than the minimum wage were taken out from sample (11% of formal workers). This is likely to be due to misreporting error and I similarly discard the 5% lowest wages out of remaining sample (self employed + informal wage earners), thus excluding mostly the zero-income earners and the part-time jobs[25]. I also trim the very top wages (1% highest of all sample). The lowest 5% and the top 1% of incomes are chosen within sex and education groups, but are constant across experience groups. In doing

[19] A registered worker is entitled to protection by the Employment laws, while an unregistered worker is not.

[20] The selection of workers from age 16 instead of older is to obtain a balanced sample of workers by potential work experience. Notice that by doing so, when I later separate the sample by education group, all groups will have workers with experience starting from one, which would not otherwise be the case if I had selected workers from age 23 for example.

[21] I do not use the entire sixteen-months window of PME to minimise attrition. As I will show, even within a month, there is significant turnover in the Brazilian data.

[22] This question is only available in PME after year 2002.

[23] This is the approach used in Van den Berg and Ridder (1998) for example.

[24] All monetary values are expressed in Brazilian currency (Real) of 06/2008 [1 US$ = 1.83 Brazilian Real].

[25] In the sample of self employed plus informal wage earners earning less than the 5th percentile, 50% are part-time workers and 37% are zero-wage earners.

so, I allow for the lowest and the top wages to reflect the relative position of males by education and females by education group in the market. However, within each of these markets, I assume that the lowest and the top wages are independent of work experience. In the model, I do however estimate equilibrium wage distributions which will vary with workers' experience, thus, average wages are allowed in the model to vary with workers' experience. Finally, PME survey reports the gross wages and the gross income of the self employed.

4 Estimation Details

In this section, I present the methodology used to estimate the model. In a model with various sectors of employment such as this, maximum likelihood methods seem quite intractable. To keep estimation as simple and transparent as possible, transition probabilities in this paper are estimated using method of moments.

The basic settings are defined to represent the Brazilian economy during the sample period 01/2002-12/2007. The unit of time is month, the time preference discount rate r is equal to the monthly interest rate, which is around 0.5%. Formal firms incur in payroll taxes (τ) which is equal to 20%, corporate taxes on profits (σ) equal to 23%, severance payments (s) equal to 8.5% and a minimum wage $w_{\min}$, about 300 Reais per month. Informal firms incur in cost C which is given by the probability of being caught by the labour authorities (Φ) *times* the fine cost, which is fixed per worker (equal to one $w_{\min}$ in practice). I estimate Φ using data on number of inspections over total formal firms, multiplied by n_1/n_2, to obtain the probability of inspection in informal firms.[26]

I start with an assumption on the distributions of wage offers $F^1(w)$ and $F^2(w)$. I assume these are Pareto distributions with parameters α^i $(for\ i = 1,2)$ chosen on a discrete grid. The last step of the estimation is to obtain α^i by solution of a minimum distance procedure. The minimum and maximum support points of $F^1(w)$ and $F^2(w)$ are obtained from data.

For every combination of α^i $(i = 1,2)$, I solve for the value functions and transition probabilities backwards. At the end of the workers' lifetime, the assumption $U_{E+1} = W^i_{E+1} = 0$ implies $d^i_E(W^i_E) = \delta^i_E$ and

$$\begin{aligned}
W^1_E(w) &= \frac{w(1+\delta^1_E \times s)+\delta^1_E UI}{(1+r)};\\
W^2_E(w) &= \frac{w}{(1+r)};\\
W^3_E &= \frac{\pi_E}{(1+r)}.
\end{aligned}$$

Comparing the values of working between sectors allows obtaining the reservation wages a period before the end of life. These are $R^{12}_E(w), R^{21}_E(w), R^{01}_E, R^{02}_E, R^{31}_E$ and R^{32}_E.

Above, unemployment insurance UI is obtained by imposing a government budget constraint. About 8.5% of receipts from labour taxes (payroll) fund UI. Hence I compute the implied UI using the government budget constraint

$$8.5\%\tau \sum_{\varepsilon} \gamma^1_{\varepsilon} \int_{\underline{w}_1}^{\overline{w}_1} x d\widetilde{G}^1_{\varepsilon}(x) = UI \times \sum_{\varepsilon} \gamma^1_{\varepsilon} \delta^1_{\varepsilon}.$$

with γ^1_{ε} equal to the empirical distribution of experience in the formal sector and $\widetilde{G}^1_{\varepsilon}(w)$ is the cross section distribution of wages by experience in the formal sector.

This enables calculation of λ^{ij}_E, λ^{3j}_E,λ^{03}_E $(for\ i,j = 1,2)$ and b_E. The value functions throughout the individuals' working lifetime are solved by iterating equations (2) through (4) backwards. *Simultaneously*,

[26] As defined earlier n_1 is the proportion of formal firms in the market, so $n_2 = 1 - n_1$. I use the estimate n_1 obtained in Meghir, Narita, and Robin (2010) for samples of similar workers. Data on inspections is from the Ministry of Labour of Brazil for the years of 2002, 2004 and 2006.

for each work experience, I calculate λ_ε^{ij}, λ_ε^{3j},λ_ε^{03}, $R_\varepsilon^{12}(w)$, $R_\varepsilon^{21}(w)$, R_ε^{01},R_ε^{02},R_ε^{31},R_ε^{32} and b_ε. The later is the value of leisure which is recovered from the model by setting $W_\varepsilon^2(\underline{w}_\varepsilon^2) = U_\varepsilon$ for all ε, as assumed earlier. I equate (1) to (4) to obtain

$$\begin{aligned} b_\varepsilon &= (1+r)\underline{W}_\varepsilon^2 - \lambda_\varepsilon^{01} \int_{R_{\varepsilon+1}^{01}}^{\overline{w}^1} W_{\varepsilon+1}^1(x)dF^1(x) - \lambda_\varepsilon^{02} \int_{R_{\varepsilon+1}^{02}}^{\overline{w}^2} W_{\varepsilon+1}^2(x)dF^2(x) \\ &\quad -\lambda_\varepsilon^{03} \max\{W_{\varepsilon+1}^3, \underline{W}_{\varepsilon+1}^2\} - [1-d_\varepsilon^0]\underline{W}_{\varepsilon+1}^2. \end{aligned}$$

with $d_\varepsilon^0 = \lambda_\varepsilon^{01}\overline{F}^1(R_{\varepsilon+1}^{01}) + \lambda_\varepsilon^{02}\overline{F}^2(R_{\varepsilon+1}^{02}) + \lambda_\varepsilon^{03} 1(W_{\varepsilon+1}^3 > U_{\varepsilon+1})$.

Below I show how the transition probabilities are recovered.

From the labour force survey, I use the proportion of unemployed workers who move from unemployment to job (D_ε^{0j}; $j = 1,2,3$), the proportion of formal employees who move to unemployment, to another job in the same sector or to the informal sector (D_ε^{1j}; $j = 0,1,2$), similar ones for employees initially in the informal sector ($D_\varepsilon^{2j}; j = 0,1,2$) and the proportion of self employed who become unemployed, formal or informal wage earners (D_ε^{3j}; $j = 0,1,2$).

The transition parameters of the model are chosen to match transitions observed in data, such that for $i = 1,2,3$, the job destruction rates are

$$\delta_\varepsilon^i = D_\varepsilon^{i0};$$

and the arrival rates to unemployed are

$$\begin{aligned} \lambda_\varepsilon^{01}\overline{F}^1(R_{\varepsilon+1}^{01}) &= D_\varepsilon^{01}; \\ \lambda_\varepsilon^{02}\overline{F}^2(R_{\varepsilon+1}^{02}) &= D_\varepsilon^{02}; \\ \lambda_\varepsilon^{03} 1(W_{\varepsilon+1}^3 &> U_{\varepsilon+1}) = D_\varepsilon^{03}. \end{aligned}$$

Now, the probabilities of transition across sectors of employment depend on the current worker's wage w. In particular, for $i,j = 1,2$ the transition rates from sector i to j at wage w are $\lambda_\varepsilon^{ij}\overline{F}^j(w)$. To match with the average transition from data D_ε^{ij}, we need to integrate the model probabilities of transition across wages (w) using the equilibrium distribution of wages in sector j. Let $\widetilde{G}_\varepsilon^j(w)$ be the proportion of employees earning less than w in sector j from data

$$\begin{aligned} \int \lambda_\varepsilon^{ij}\overline{F}^j(x)d\widetilde{G}_\varepsilon^j(x) &= D_\varepsilon^{ij} \\ &\Rightarrow \lambda_\varepsilon^{ij} = \frac{D_\varepsilon^{ij}}{\int \overline{F}^j(x)d\widetilde{G}_\varepsilon^j(x)}, \end{aligned}$$

From self employment ($i = 3$), given that the value of the self employed is deterministic, W_ε^3, the estimated probability of transition to become a wage earner in sector j is

$$\lambda_\varepsilon^{3j} = \frac{D_\varepsilon^{3j}}{\overline{F}^j(R_{\varepsilon+1}^{3j})}; \quad j = 1,2.$$

In addition, to obtain plausible estimates for the above transition rates across sectors of employment λ_ε^{ij}, i.e. which implies that the total job separation probability, d_ε^i, is in the interval $[0,1]$ for $i = 1,2,3$, I assume that each rate must be less than $1 - \delta_\varepsilon^i$ for workers in sector i and less than 1 for the unemployed. This is imposed using the following constraints (for $j = 1,2$)

$$
\begin{aligned}
\lambda_\varepsilon^{ij} &= \min\left\{1-\delta_\varepsilon^i, \frac{D_\varepsilon^{ij}}{\int \overline{F}^j(x) d\widetilde{G}_\varepsilon^j(x)}\right\}; \\
\lambda_\varepsilon^{3j} &= \min\left\{1-\delta_\varepsilon^3, \frac{D_\varepsilon^{3j}}{\overline{F}^j(R_{\varepsilon+1}^{3j})}\right\}; \\
\lambda_\varepsilon^{03} &= \min\left\{1, \frac{D_\varepsilon^{03}}{1(W_{\varepsilon+1}^3 > U_{\varepsilon+1})}\right\}; \\
\lambda_\varepsilon^{0j} &= \min\left\{1, \frac{D_\varepsilon^{0j}}{\overline{F}^j(R_{\varepsilon+1}^{0j})}\right\}.
\end{aligned} \tag{12}
$$

Equations (5) through (7) describe the evolution of the measure of self employed, formal employee and informal employee with potential experience ε. Given $F^1(w)$ and $F^2(w)$, the estimates of transition probabilities and the initial conditions $[M_1^1(w), M_1^2(w), m_1^3]$, the model composition of workers over the life cycle, $M_\varepsilon^1(w)$, $M_\varepsilon^2(w)$ and m_ε^3, are solved recursively. From data, I construct for the individuals with the minimum level of experience the stock of workers in each sector ($\widetilde{m}_1^i$) and the distribution of wages in the formal ($\widetilde{G}_1^1(w)$) and in the informal sector ($\widetilde{G}_1^2(w)$) to give the initial conditions, i.e. $M_1^1(w) = \widetilde{m}_1^1 \widetilde{G}_1^1(w)$, $M_1^2(w) = \widetilde{m}_1^2 \widetilde{G}_1^2(w)$ and $m_1^3 = \widetilde{m}_1^3$. Thus, iteratively, the model composition of the workforce at all other levels of experience is solved for.

The main result is that the model equilibrium distributions of wages accepted by workers is $G_\varepsilon^i(w) = M_\varepsilon^i(w)/M_\varepsilon^i(\overline{w}_\varepsilon^i)$. The right hand side are functions of $F^1(w)$ and $F^2(w)$, which are not showed analytically due to their complexity. *These establish the relationship between the equilibrium accepted wage distributions and the wage offers distributions.*

I repeat the process until now for other values of α^i (i.e. other $F^1(w)$ and $F^2(w)$).

Given the relationship between $G_\varepsilon^i(w)$, and $F^1(w)$ and $F^2(w)$, the solution of $F^1(w)$ and $F^2(w)$ is obtained by *minimum distance*. It consists of finding the pair (α^1, α^2) so that the model distribution of accepted wages best approximates the cross section distribution of wages. In practice, I will search on a discrete grid of α^1 and α^2 which minimises

$$\sum_i \sum_\varepsilon \sum_w (G_\varepsilon^i(w) - \widetilde{G}_\varepsilon^i(w))^2$$

across 600 months of experience, formal and informal sectors, and for 100 levels of wages chosen on a discrete grid.

I use normal kernel estimates for the wage densities $\widetilde{g}_\varepsilon^i(w)$ by sex, education and experience group. These are the densities of earned wages at the date of the first interview. Then, I numerically integrate these densities to obtain the empirical c.d.f.'s $\widetilde{G}_\varepsilon^i(w)$.

Now, I proceed with details on the estimation of the firms' productivities and profits in the steady state. I estimate the weights γ_ε using the distribution of experience in the data.

Using (8) and (9), the firms' first order condition in each sector delivers the productivities in each sector

$$
\begin{aligned}
p_1 &= K_1^{-1}(w) = w \frac{\sum_\varepsilon (1+\tau+\delta_\varepsilon^1 s) \ell_\varepsilon^1{\prime}(w) \gamma_\varepsilon}{\sum_\varepsilon \ell_\varepsilon^1{\prime}(w) \gamma_\varepsilon} + \frac{\sum_\varepsilon (1+\tau+\delta_\varepsilon^1 s) \ell_\varepsilon^1(w) \gamma_\varepsilon}{\sum_\varepsilon \ell_\varepsilon^1{\prime}(w) \gamma_\varepsilon}; \\
p_2 &= K_2^{-1}(w) = w + C + \frac{\sum_\varepsilon \ell_\varepsilon^2(w) \gamma_\varepsilon}{\sum_\varepsilon \ell_\varepsilon^2{\prime}(w) \gamma_\varepsilon}.
\end{aligned}
$$

where $\ell_\varepsilon^i(w) = \frac{1}{n_i} \frac{dM_\varepsilon^i(w)}{dF^i(w)}$ denotes labour force size and $\ell_\varepsilon^i{\prime}(w)$ is obtained from the numerical derivative of labour force size with respect to wages.

Having estimated the productivities, the profit functions in the formal and in the informal sector follow from equations (8) and (9).

In the above estimations, the unit of time is month. The values, measures of workforce, mobility parameters and equilibrium accepted wage distributions are calculated for every month of work experience until the 600th month (or 50 years). The choice of month instead of year is to minimise attrition problems. In order to reduce the cost of computing the transition probabilities and workforce measures, I constrained the transitions and cross section distributions from data to vary only across intervals of experience. I split 1-600 into seven intervals [1-72, 73-120, 121-181, 182-240, 241-360, 361-480 and 481-600 months].

Finally, I take into account workers' observed heterogeneity by assuming that markets can be segmented by sex and education. I separate the sample by sex and three groups of education and I estimate the model for each of those six markets.

5 Estimation Results

This section presents the main results of the estimated model, which are the underlying parameters used to construct the value functions and the composition of the workforce over the life cycle. I start with the wage offers distribution in the formal and in the informal sector. I assumed earlier that these distributions are Pareto with parameters which are estimated using *minimum distance*. The estimated Pareto parameters by sector - formal (α^1) and informal (α^2) - and by sample of individuals according to sex and education are, respectively, 1.6 and 2.9 for males with low education, 1.4 and 2.8 for males with medium education, and 0.7 and 1.5 for males with high education. For females, 2.4 and 1.7 for those with low education, 1.8 and 1.9 for those with medium education, and 1.2 and 1.5 for those with high education.

Figures 9 through 14 in the Appendix report, by sex and education groups, estimates of the model transition probabilities across sectors of employment and unemployment. The horizontal axis is potential work experience in years. Job destruction rates (δ_ε^i) are decreasing functions of the worker's experience. While these do not differ much between males and females, they tend to be higher for low education than for high education workers. Only for high education males in the formal sector and self employed, it shows a U-shape form, i.e. it tends to increase with experience when they get older.

The re-employment rates (λ_ε^{01} and λ_ε^{02}) with a firm (formal or informal) initially increases with work experience but then decreases when experience gets high. As for the probability of entry into self employment (λ_ε^{03}), except for high education females, it behaves as an increasing function of work experience for all other sample groups. The curve is steeper for males with low education, but flatter for females regardless of education level. The finding for males seem consistent with Lucas' and Evans and Jovanovic's framework in which the high education individuals find more easily opportunities to self employment. On the contrary, for the vast majority of self employed males, those with low education, work experience clearly plays a larger role.

Transitions within the formal sector (λ_ε^{11}) decrease with work experience for low education males but increases for medium and high education ones. The same holds for females, except for the medium education ones, for which this probability is decreasing with experience. Mobility within the informal sector (λ_ε^{22}) exhibits a U-inverted shape with experience for low and high education groups and is flat or increasing with experience for medium education ones.

The mobility rates from being an informal wage earner or self employed to a job in the formal sector, i.e. λ_ε^{21} and λ_ε^{31} are very low in general, except for workers with medium and high education, who seem to get more easily a job with a formal firm. In contrast, the λ_ε^{12} and λ_ε^{32}estimates are much larger in general and for some levels of experience it has reached the constraints (12) I imposed on the estimates of the mobility rates. These results confirm that admission into an informal sector job is almost always possible and workers do not always go because the value offered in that sector is lower then their current value in the formal sector or as self employed.

Now, I turn to the main results of this paper. In the Appendix, Figures 3 through 8 depict the composition of the workforce over life cycle, by sex and education groups. The figures on the left are the empirical proportion of workers in each employment status and the figures on the right are the ones predicted using the model counterparts which are described in the equations (5)-(7).

A comparison of the empirical and the predicted proportions of workers in each category of employment indicates that the model is able to reproduce similar patterns observed in data. It shows that formal employment increases with experience for younger workers then decrease for older workers. It shows that informal employment decreases with work experience for workers with 0-9 years of schooling and that it is somehow U-shaped for workers in the 10-11 and 12+ education groups. The model also matches the observed pattern for unemployment across all sample groups. Finally, it reproduces well the increasing fraction of workers under self employment. Self employment increases with experience suggesting the need to learn about good projects to undertake as self employed. The fraction of self employment is larger for low education females than for low education males, as the results for groups of education 0-9 and 10-11 years show. In contrast, the self employment rate is superior for high education males than for high education females. These findings suggest that education plays a larger role in determining self employment among males. This could be related to the activities in which self employed males work which seem to demand relatively more education[27] than would be required in activities in which self employed females work. In addition, it could reflect the fact that low education females have more children and, as a result, they tend to choose self employment in order to have more work flexibility than they would otherwise obtain by working for a firm.

The model composition of workers by sector of employment and also by value if the job is in the formal or in the informal sector are functions of the model earnings distribution in the formal $G^1_\varepsilon(w)$ and in the informal sector $G^2_\varepsilon(w)$. That those distributions fit well the empirical wage distributions is what guarantees an approximate solution for the offers distribution. Table 10 in Appendix shows, for males with low education, how well the earnings distribution obtained from the model fits the empirical wage distributions in the formal and in the informal sector. Because it would take a lot of space displaying the results for all years of experience, I show them only when experience is equal to 5, 10, 20, and 30 years. The model fits reasonably well the observed mean wages in the formal and in the informal sector. This is due to the quadratic form of the criterion function in the minimum distance procedure I use. The model, however, predicts higher standard deviation of log wages than the empirical ones. In general low wages tend to be underestimated while high wages overestimated. The fit of the 25th percentile and median wages are better in the formal rather than in the informal sector.

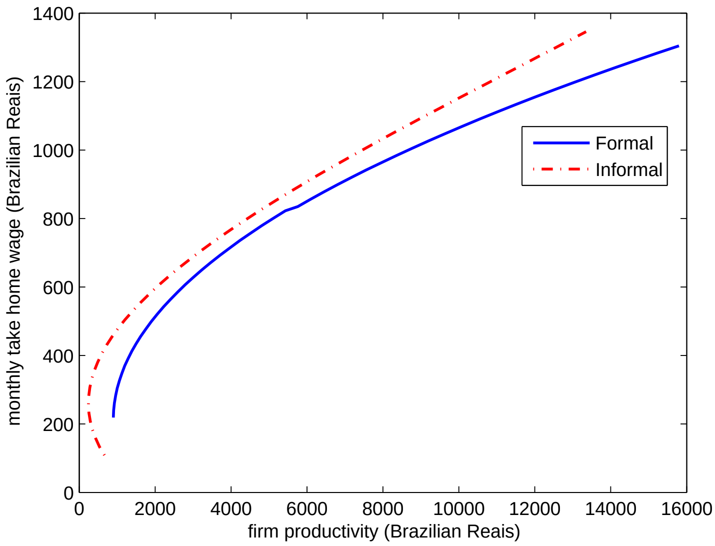
The estimates of the value of leisure, b_ε, are on average much lower than the minimum wage in the informal sector (95 Reais). The average of non-labour time is -964, -1635 and -8312 Reais for males with education 0-9, 10-11 and 12 or more years, respectively. While for females, these averages by the same education groups are -231, -455 and -3820 Reais. The fact that on average individuals value leisure negatively is due to outside opportunities while unemployed being much higher than while in an informal sector job. Although it has not been displayed, by experience, the value of leisure is U-shaped. It starts positive, then decreases until mid-experience, then it increases until becoming positive again in the last years of individuals' working lifetime. The value of leisure at end of life is close to the minimum wage in the informal sector, due to the fact that at the end of life, workers face similar opportunities either working informally or unemployed.

Finally, Figure 2 plots the equilibrium wages (take-home pay) by productivity in the formal and in the informal sector. At the top, I have truncated the plots at the 99th percentile of (gross) wage distributions in each sector. Interestingly, this figure reveals that the informal sector has to pay more than a formal sector job with the same productivity. This is consistent with a compensating wage differentials view as more non-wage benefits tend to be provided in the formal sector, where workers are entitled to benefits by law. At the same time, because top wages are relatively more predominant in the formal sector, this implies higher average wages (even *after tax*) in this sector, which is compatible with what is found in data.

[27] or anything strongly correlated with it, such as individual ability.

FIGURE 2

Wages by Productivity, Low education Males



A last interesting aspect of this figure, also similarly found in Meghir, Narita and Robin (2010), is that very high productivity firms have a very high monopsony power (productivity is at least ten times larger than paid wages). Furthermore, formal sector firms enjoy relatively more monopsony power than informal sector firms.[28] Again, firms in the informal sector need to pay more to attract workers as they need to compensate them at least for lack of mandatory benefits.

6 Counterfactual Simulations

6.1 Labour Market Policies: Equilibrium Effects on Informality and Welfare

In the interest of promoting welfare and lowering wage inequality, should informal sector firms be shut down? In this section, I use the estimates obtained for low education males to examine the impact of policies towards decreasing informality. I focus on the low education group because self employment and informality are particularly important among these individuals. Inspections of labour is one type of policy which has been important in Brazil since 1996. Labour inspections may close firms down, or impose a penalty fee which does not imply that they leave the market. I look at these two different possibilities.[29]

In all simulations of this section, I keep the government revenue constant by adjusting the corporation tax paid by formal firms. Table 5 shows results of a simulation which decreases to zero the probability of job offers from informal sector firms. As expected, aggregate unemployment increases. The impact on unemployment is however small. Such an extreme scenario where no informal firms operate leads to a 3.5pp increase in unemployment. Most of previously wage earners of the informal sector become self employed and formal employment raises by 1.3pp.

These simulations also show that eliminating offers from informal sector firms has a downward effect on the value of the unemployed and self employed workers. There are much fewer possibilities of finding a job or a job with a better value, thus the unemployed's welfare decreases by 1% and the self employed's by

[28]The 90th percentile of productivity is around \$7,000 in the formal sector and around \$2,000 in the informal sector.

[29]Most labour inspections in pratice are triggered by anonymous complaints by employees in firms (Almeida and Carneiro, 2009). Thus, should not have a direct impact on those self employed.

2%.[30] On the other hand, the value of formal sector employees increases by 3%. Overall, workers' welfare improve by 1%. As for firms, their average welfare reduces because there are fewer firms in the market. Nonetheless, this simulation shows that formal firms' welfare increases by 8% because labour force size rose and corporation taxes were lowered.

The absence of informal sector firms takes most low paid wage jobs out of the market. Because the formal sector is subject to minimum wage laws, wages become relatively higher at the bottom of the wage distribution. Wage inequality falls. I only look at the inequality among wage earners since the income of those self employed is deterministic.

Remarkably, having the option of self employment seems to minimise the impact of shutting down informal sector firms on unemployment. Even though much of the informality of wage earners is among the youngest workers, who face fewer opportunities to enter into self employment, there seems to be enough of these opportunities, preventing higher unemployment. An increase of 3.5pp in unemployment is a contrast to the findings in Meghir, Narita and Robin (2010) where self employment is not available. For males with low education, they find that unemployment increases by 9pp in a richer region and 10pp in a poorer region in Brazil.

Yet, why does worker's welfare increase only by 1%, when simulating the elimination of informal sector firms? First, firms' location across formal and informal sectors is exogenous. In Meghir, Narita and Robin (2010), where firms are allowed to become formal after policy changes, welfare changes in the range -12% to +11%, depending on the region. Second, arrival rates are exogenous. In their paper, when increases in the fraction of formal firms lead to increases in job arrivals from that sector, given assumptions on a matching process, welfare actually increases by 15-37%, also depending on a particular region.[31] Third, another reason for a small increase in workers' welfare is that the self employed and informal wage earners are, on average, very similar in terms of lifetime value of their earnings. See Figure 15 in the Appendix. Thus, a simulation which mostly trades informal sector employment for more self employment should not have improved much the workers' welfare.[32]

That the self employed and informal wage earners seem comparable in Brazil is very interesting. These findings seem in line with those in McKenzie, de Mel and Woodruff (2008) showing that those self employed in developing countries are more similar to wage earners than to owners of large entreprises. If they have similar productive characteristics, their expected lifetime income should be also similar on average. This is what I find in the estimations of this paper. In addition, eliminating jobs in informal sector firms does not significantly reduce informality, given that the majority of those self employed evade taxes. From a tax collection perspective, if taxes are more enforceable in informal sector firms than in businesses run by the self employed (since informal firms are larger, see Table 2), offering tax schemes which allow small informal firms to operate, and providing them incentives to grow and hire workers, seems a better alternative.

Now, I analyse the impact of marginal increases in the cost of informality. The last column of Table 5 display results of simulations in which I increase the parameter cost, C, by 10%. An increase in costs induces informal firms to adjust wages down. Since they pay lower than the formal sector, wages decrease in the bottom of the entire wage distribution. Overall, workers' welfare improved because on formal sector wages went up. The main cause is the option of self employment, which improves the rent-sharing between firms

[30]To obtain the mean welfare, I sum the discounted values of the average worker over the lifetime and across sectors. I weight by the distribution of experience γ_ε

$$\sum_{\varepsilon=1}^{E} \gamma_\varepsilon \frac{1}{(1+r)^\varepsilon} \left\{ m_\varepsilon^1 \int W_\varepsilon^1(x) dG_\varepsilon^1(x) + m_\varepsilon^2 \int W_\varepsilon^2(x) dG_\varepsilon^2(x) + m_\varepsilon^3 W_\varepsilon^3 + u_\varepsilon U_\varepsilon \right\}$$

[31]Although allowing for endogenous arrival rates would not be extremely difficult to implement in this paper, they would only make sense if I further allow for firms' choice of sector. The latter, however, would severely complicate the present analysis. Results of simulating the elimination of informal sector firms should then be interpreted with caution.

[32]It is possible that there is underreporting in the labour income of the self employed. Hurst, Li and Pugsley (2010) shows that the self employed in the US underreport their income by 30%. To get a sense of what would have been the welfare improvement of shutting down the informal sector if the self employed income were accurately reported, I assume that they are 10% higher. The welfare gain would have been 6% instead of 1% obtained earlier.

TABLE 5

Simulating the Impact of Shutting Down Informal Sector Firms or Increasing the Informality Cost

	Benchmark	No Informal Sector Offers	Increase Informality Cost (10%)
Wages percentiles (log)			
P10	5.50	5.64	5.46
P25	5.80	5.89	5.78
Median	6.28	6.29	6.34
P75	6.77	6.80	6.87
P90	7.22	7.29	7.45
Inequality			
w(75)/w(25)	2.64	2.48	2.96
w(90)/w(10)	5.55	5.23	7.36
Workers' Welfare	28.1	28.4	30.1
(Lifetime, \$1,000)			
Average Firm's Welfare	2028.8	1788.7	2620.2
(per month)			
Formal Firms' Welfare	4142.3	4471.6	5427.7
(per month)			
Composition of Workforce (%)			
Formal Employee	41.8	43.1	42.0
Informal Employee	16.8	0.0	17.3
Self Employed	29.5	41.5	28.8
Unemployed	11.9	15.4	11.9

Note: Simulations performed for males with low education. Wages are in log terms, of the monthly income in Reais of 2008. All simulations keep government revenue constant via adjustments in corporation taxes. The workers' welfare is the mean present value obtained by the weighted sum of individuals' discounted values across all years of experience and sectors of work. The firms' welfare is given by their profits in the steady state.

and employees. [33]

With stricter enforcement, informal employees attempt to get formal sector jobs, and the fact that the self employment exists increases formal firm size even more than it would be expected without such an option and given that competition among firms is the same. That labor force increases in the formal sector causes offered wages to increase, so workers' welfare to also increase in that sector. This increase in welfare is translated into an increase in welfare of informal sector wage workers and of the self employed. The increase of the latter however is relatively smaller, such that the value of being informal wage earner is now a little larger than that of being self employed, for most levels of experience.[34] This explains the paradoxical result that when cost of informality increases, the fraction of informal wage earners increases, while self employment decreases. Note however that these changes are probably economically insignificant.

In sum, changes in the informality cost have very little impact on the composition of the workforce and they increase the fraction of formal sector workers only by 0.3pp. An increase on the probability of catching an informal firm or in the penalty cost reduce wages in the informal sector and increase wage inequality. On the other hand, it improves significantly workers' and firms' welfare.

6.2 Equilibrium Impact of Changes in Taxes and Benefits in the Formal Sector

In this section, I simulate the impact of changes in tax/benefits of the formal sector and of changes in the legal minimum wage. The aim is to evaluate the effect of these fiscal changes on the employment composition over the life cycle, on wage inequality and welfare. For example, by how much would employment composition change if formal sector firms were less heavily taxed? What is the extent to which the government can use tax and minimum wage policies to increase formality of workers, in the presence of a large non-compliant sector (self employed and informal sector firms)? These questions are motivated by recent literature and debate on how stricter regulatory costs affect informality.[35]

The table 6 presents the main results of simulations performed for low education males. The table shows that equilibrium results of changes in payroll tax (on firms), severance rate and in unemployment insurance (UI) are insignificant on the composition of workforce. When payroll tax on firms is reduced by 5 percentage points only wages are affected. Formal firms respond to this policy by increasing wages in the formal sector, thus shifting all wages up. Formal firms' welfare reduces, while keeping welfare of all other firms and workers unchanged. As the table shows, the impact is positive and its extent is different across wage levels. High earners benefitted more from the payroll reduction and that implied an increase in wage inequality, especially based on 90/10th index.

When severance rate is reduced by 1 percentage point, again, mostly a direct impact is observed. Because severance directly benefits formal sector workers, its reduction causes a 0.1pp fall in the fraction of formal employees who become self employed. Because severance represents a cost for formal sector firms, these attempt to increase wages due to lowered costs. Everyone but informal sector firms are worse off. In particular, workers in the formal sector are made worse off due to decrease of expected benefits, despite receiving now higher wages. Results also show that the 90/10th wage inequality increases.

The increase of the unemployment insurance by 50%[36], also increases the relative attractiveness of formal sector jobs. Wages in the formal sector reduce by a small percentage while wages in informal sector increase by a similar percentage such that the overall wage distribution is almost unchanged. Because the UI benefit is increased and so are wages in the informal sector, workers welfare increase by 0.5%. Firms

[33]Similar to results in Meghir, Narita and Robin (2010) an increase in the cost of informality by 10% may increase workers' welfare, despite lowered wages in the informal sector. In their case, this is because of increased competition in the formal sector, which leads to higher wages and value of jobs in that sector.

[34]This is because the opportunity of getting a formal job while working for an informal firm is much larger than while working as self employed, i.e. λ_{21} is much larger than λ_{31}, see plot 9.

[35]For a discussion see, for example, Almeida, Carneiro and Narita (2010), Fernandes, Gremaud and Narita (2005) and references therein.

[36]Above its estimate which is around 1,103 Reais, or nearly three minimum wages.

TABLE 6

Simulating the Impact of Fiscal Policies

	Benchmark	Payroll Tax Reduction	Severance Rate Reduction	UI Increase	Minimum Wage Increase
Wages percentiles (log)					
P10	5.50	5.52	5.51	5.50	5.51
P25	5.80	5.83	5.80	5.80	5.81
Median	6.28	6.30	6.28	6.28	6.26
P75	6.77	6.80	6.78	6.77	6.73
P90	7.22	7.26	7.23	7.22	7.14
Inequality					
w(75)/w(25)	2.64	2.66	2.66	2.63	2.53
w(90)/w(10)	5.55	5.67	5.58	5.55	5.12
Workers' Welfare	28.07	28.07	27.88	28.21	27.91
(Lifetime, $1,000)					
Average Firm's Welfare	2028.8	2004.0	2028.3	2022.7	1811.2
(per month)					
Formal Firms' Welfare	4142.3	4080.4	4137.8	4133.5	3608.3
(per month)					
Composition of Workforce (%)					
Formal Employee	41.8	41.8	41.7	41.8	41.8
Informal Employee	16.8	16.8	16.8	16.8	16.8
Self Employed	29.5	29.5	29.6	29.5	29.5
Unemployed	11.9	11.9	11.9	11.9	11.9

Note: Simulations performed for males with low education. Wages are in log terms, of the monthly income in Reais of 2008. All simulations keep government revenue constant via adjustments in corporation taxes. The workers' welfare is the mean present value obtained by the weighted sum of individuals' discounted values across all years of experience and sectors of work. The firms' welfare is given by their profits in the steady state. Payroll taxes are reduced by 5pp, severance rate by 1pp, UI is increased by 50 percent and minimum wage by 10 percent.

are worse off in the informal sector because now they pay higher and in the formal sector because corporate taxes were adjusted up to compensate for the increase in unemployment compensation.

The last simulation is to evaluate the impact of changes in the legal minimum wage. For example, suppose that the federal government increases it by 10%. Again, there is no effect on the composition of the workforce. To recall, in these simulations, I assume firms can never go inactive or change sectors.[37] When formal firms are faced with higher minimum pay, they attempt to lower wages above the minimum, i.e. the formal wage offers distribution shifts to the left. Lowest wages slightly increase but all other percentiles decrease. The consequence is a substantial fall in wage inequality. Lower formal sector wages (on average) is the main reason for a decline in workers' welfare by 0.6%. Informal firms attempt to increase wages to keep their workers, which causes their profits to fall. Formal firms, despite paying lower on average, have to pay higher corporation taxes so as to keep government revenue constant, thus their profits also fall. On average, firms are worse off by 11%.

In sum, the equilibrium impact of tax/benefit and minimum wage policies is insignificant on the composition of the workforce (aggregate and over the life cycle). Nonetheless, all policy simulations performed for low education males show significant impact on wages, thus on wage inequality. In particular, minimum wage increases seem more effective in lowering wage inequality. However, in this case there is a strong trade off between wage inequality and the welfare of firms and workers.

7 Conclusion

This paper offers an alternative approach to study self employment in developing countries. In the labour force data, entry into self employment increases sharply with age, suggesting that individuals seem to learn with work experience about good business opportunities to undertake. I address this feature found in many data by building on a life cycle search model where the transition probabilities are allowed to vary by potential work experience.

One important contribution from this paper is a model which, besides unemployment, accommodates the three main categories of employment of a developing economy: the formal wage earners, the informal wage earners and the self employed workers. Also, in contrast to other models of self employment, I abstract from competitive labour market assumptions and allow firms to post wages following the Burdett-Mortensen (1998)'s approach. This is particularly important for analysing the general equilibrium effects of counterfactual policies.

The estimated results show that a labour search model with mobility processes which depend on worker's potential work experience can reproduce well the life cycle composition of workers as observed in Brazilian data. The model also allows comparing the value of jobs across sectors. Interestingly, I show that the lifetime value of a job as self employed is similar to that of wage earners in the informal sector, suggesting that they have similar productivity characteristics in developing countries like in Brazil.

The model is used to perform counterfactual policies for low education males. When simulating an economy where job offers from informal sector firms become inexistent, workers' welfare increases by a small proportion. This is expected since firms are not allowed to move into the formal sector. Nonetheless, it shows that most of previously informal wage earners become self employed, having a small increase in unemployment.

When simulating an increase of 10% in the informality cost, the effects on the composition of workforce are small. The greatest impact is on wages of the informal sector, which fall significantly, causing an increase in overall wage inequality. On the other hand, this policy seems effective in improving workers' and firms' welfare.

Finally, future research is planned to extend this paper in an important way. The assumption that wage offers do not vary by work experience is probably rejected by any data. An extension would allow for posted

[37] A 10% increase in minimum wage does not cause negative profits for any firm type.

wages to vary by work experience.

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TABLE 7

Summary of individual data, by experience (0-9 years of schooling)

		Work Experience (Years)			
	All sample	0-10	11-19	20-30	>30
Number of Individuals	342,520	66,725	86,976	85,859	102,960
Unemployed	47,389	18,256	12,408	8,665	8,060
Formal employee	138,443	21,249	39,298	38,910	38,986
Informal employee	63,285	19,578	16,917	12,960	13,830
Self employed	93,403	7,642	18,353	25,324	42,084
Self Employed/Active Workforce (%)	27.3	11.5	21.1	29.5	40.9
Censored observations (%)					
Unemployed	47.0	49.7	45.8	43.9	46.2
Formal employee	23.9	27.1	24.4	22.2	23.3
Informal employee	30.1	32.8	29.3	28.4	28.7
Self employed	29.9	35.2	29.4	28.7	29.9
Transitions (% of workers by initial status)					
Unemployed – Formal employee	1.55	1.51	1.53	1.77	1.43
Unemployed – Informal employee	4.15	4.49	4.07	4.55	3.11
Unemployed – Self employed	8.73	3.74	8.61	12.46	15.29
Formal employee – Formal employee	0.57	0.90	0.60	0.56	0.37
Formal employee – Unemployed	1.07	2.03	1.23	0.83	0.66
Formal employee – Informal employee	0.23	0.39	0.29	0.17	0.14
Formal employee – Self employed	0.07	0.09	0.07	0.05	0.06
Informal employee – Informal employee	2.39	3.13	2.40	2.21	1.55
Informal employee – Unemployed	4.62	6.15	4.92	4.05	2.78
Informal employee – Formal employee	0.54	0.49	0.78	0.52	0.31
Informal employee – Self employed	0.44	0.24	0.40	0.56	0.63
Self employed – Unemployed	2.75	5.37	3.61	2.81	1.89
Self employed – Informal employee	0.73	1.57	1.14	0.73	0.40
Self employed – Formal employee	0.18	0.24	0.22	0.24	0.11

Note: Brazilian Labor Force Survey 2002-2007. Transitions are per month, starting from the individuals' first interview. They show percentages of individuals by initial status who moved to other statuses, as the rows indicate.

TABLE 8

Summary of individual data, by experience (10-11 years of schooling)

		Work Experience (Years)			
	All sample	0-10	11-19	20-30	>30
Number of Individuals	249,424	125,326	64,999	40,422	18,677
Unemployed	38,012	26,572	7,125	3,205	1,110
Formal employee	140,254	69,137	40,209	22,671	8,237
Informal employee	35,189	21,146	7,382	4,305	2,356
Self employed	35,969	8,471	10,283	10,241	6,974
Self Employed/Active Workforce (%)	14.4	6.8	15.8	25.3	37.3
Censored observations (%)					
Unemployed	41.0	40.9	41.1	40.5	44.9
Formal employee	23.5	23.1	23.3	23.4	27.2
Informal employee	27.0	26.9	26.9	26.5	28.3
Self employed	28.3	29.7	27.5	26.9	30.0
Transitions (% of workers by initial status)					
Unemployed – Formal employee	2.02	2.18	1.81	1.63	0.49
Unemployed – Informal employee	3.42	3.83	2.88	1.94	1.14
Unemployed – Self employed	3.82	2.53	5.98	7.97	8.99
Formal employee – Formal employee	0.70	0.89	0.56	0.47	0.42
Formal employee – Unemployed	1.18	1.60	0.92	0.61	0.55
Formal employee – Informal employee	0.19	0.27	0.12	0.10	0.07
Formal employee – Self employed	0.04	0.04	0.03	0.05	0.03
Informal employee – Informal employee	1.63	2.00	1.41	0.79	0.59
Informal employee – Unemployed	4.36	5.42	3.47	2.21	1.54
Informal employee – Formal employee	0.62	0.75	0.35	0.54	0.47
Informal employee – Self employed	0.15	0.14	0.15	0.09	0.30
Self employed – Unemployed	2.79	5.56	2.68	1.84	1.02
Self employed – Informal employee	0.43	0.96	0.39	0.21	0.16
Self employed – Formal employee	0.23	0.40	0.24	0.15	0.10

Note: Brazilian Labor Force Survey 2002-2007. Transitions are per month, starting from the individuals' first interview. They show percentages of individuals by initial status who moved to other statuses, as the rows indicate.

TABLE 9

Summary of individual data, by experience (12+ years of schooling)

		Work Experience (Years)			
	All sample	0-10	11-19	20-30	>30
Number of Individuals	108,742	52,963	28,078	19,095	8,606
Unemployed	8,476	5,577	1,595	965	339
Formal employee	66,244	32,602	18,661	11,159	3,822
Informal employee	15,686	10,017	2,718	1,843	1,108
Self employed	18,336	4,767	5,104	5,128	3,337
Self Employed/Active Workforce (%)	16.9	9.0	18.2	26.9	38.8
Censored observations (%)					
Unemployed	41.8	41.9	39.6	43.0	46.3
Formal employee	26.5	25.2	27.0	28.5	29.4
Informal employee	26.4	26.6	24.8	26.5	28.5
Self employed	29.8	29.8	29.7	29.2	30.9
Transitions (% of workers by initial status)					
Unemployed – Formal employee	2.03	2.25	1.97	1.45	0.00
Unemployed – Informal employee	2.57	2.99	1.56	1.64	3.30
Unemployed – Self employed	3.99	2.90	4.77	7.64	8.24
Formal employee – Formal employee	0.62	0.86	0.41	0.38	0.19
Formal employee – Unemployed	0.76	1.01	0.62	0.33	0.48
Formal employee – Informal employee	0.17	0.27	0.08	0.09	0.07
Formal employee – Self employed	0.03	0.04	0.04	0.00	0.00
Informal employee – Informal employee	1.03	1.20	0.83	0.74	0.51
Informal employee – Unemployed	2.28	2.54	2.20	1.77	0.88
Informal employee – Formal employee	0.43	0.49	0.24	0.44	0.38
Informal employee – Self employed	0.19	0.14	0.34	0.22	0.25
Self employed – Unemployed	1.40	2.21	1.28	1.32	0.52
Self employed – Informal employee	0.26	0.51	0.22	0.17	0.09
Self employed – Formal employee	0.18	0.42	0.14	0.11	0.00

Note: Brazilian Labor Force Survey 2002-2007. Transitions are per month, starting from the individuals' first interview. They show percentages of individuals by initial status who moved to other statuses, as the rows indicate.

TABLE 10

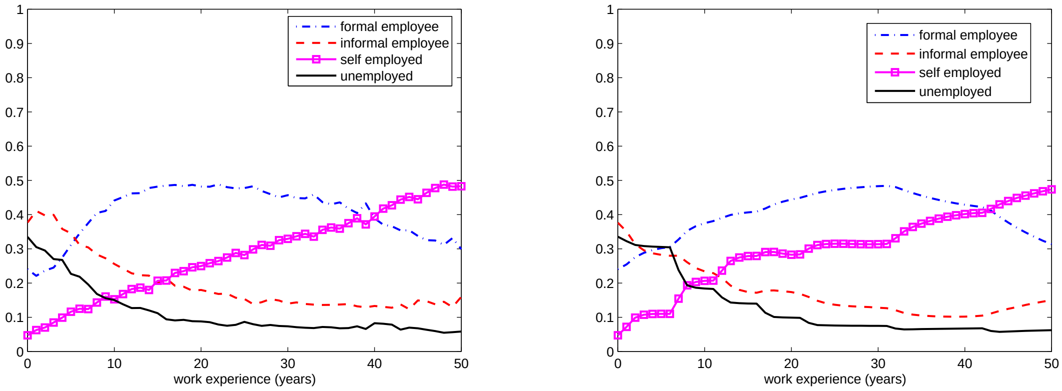
Fit of the Model Equilibrium Wage Distributions (numbers are log of monthly wages)

	Work Experience							
	5 years		10 years		20 years		30 years	
	data	model	data	model	data	model	data	model
Formal Sector								
Mean	6.23	6.32	6.34	6.35	6.50	6.39	6.56	6.49
Std.Deviation	0.30	0.52	0.36	0.55	0.41	0.56	0.43	0.58
P10	5.84	5.70	5.88	5.67	6.00	5.65	6.00	5.73
P25	5.96	5.84	6.06	5.88	6.16	5.87	6.21	6.00
Median	6.17	6.21	6.26	6.26	6.42	6.30	6.50	6.42
P75	6.38	6.64	6.53	6.69	6.74	6.77	6.83	6.90
P90	6.61	7.08	6.80	7.16	7.05	7.22	7.13	7.34
Informal Sector								
Mean	5.79	5.71	5.93	5.90	6.13	6.15	6.18	6.10
Std.Deviation	0.40	0.62	0.44	0.69	0.50	0.78	0.52	0.79
P10	5.19	4.96	5.35	4.97	5.45	5.06	5.55	5.06
P25	5.53	5.19	5.62	5.35	5.73	5.45	5.80	5.34
Median	5.78	5.53	5.90	5.70	6.06	6.12	6.12	5.88
P75	6.02	6.07	6.16	6.41	6.44	6.78	6.48	6.77
P90	6.29	6.74	6.48	6.93	6.80	7.17	6.86	7.17

Note: This table compares the empirical and the model distributions of accepted wages by all workers in the formal and informal sectors. This is based on sample of low education males from the Brazilian Labor Force Survey 2002-2007.

FIGURE 3

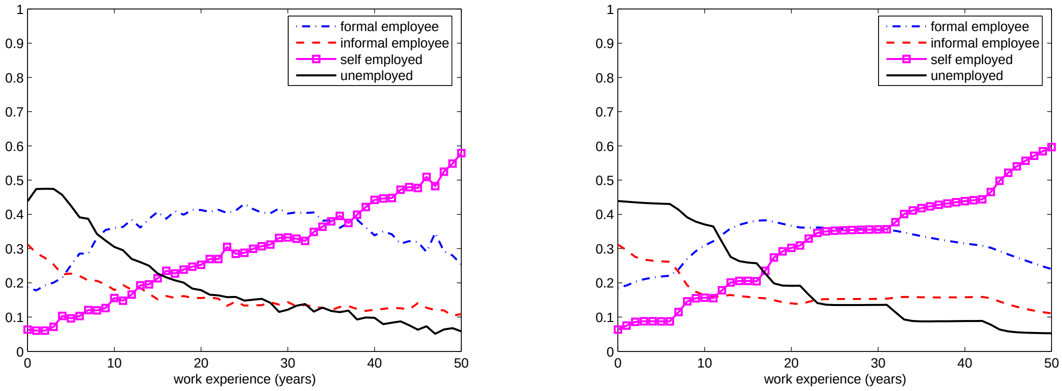
Composition of Workforce - Males, Education 0-9 years



Empirical | Model

FIGURE 4

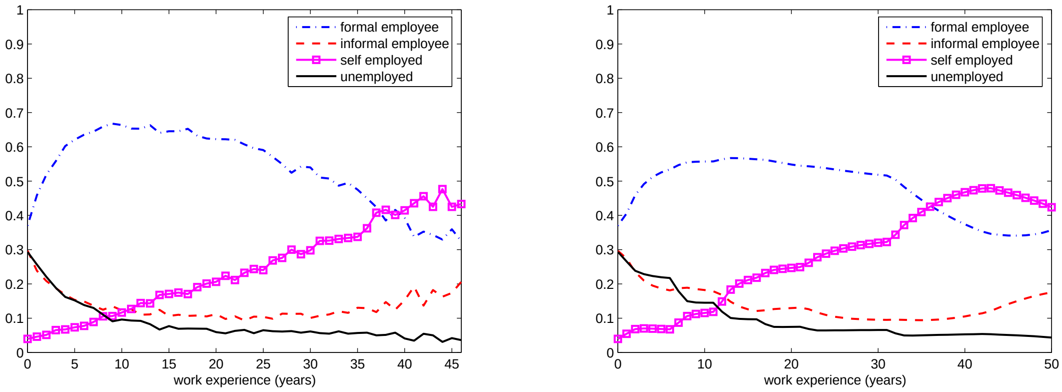
Composition of Workforce - Females, Education 0-9 years



Empirical | Model

FIGURE 5

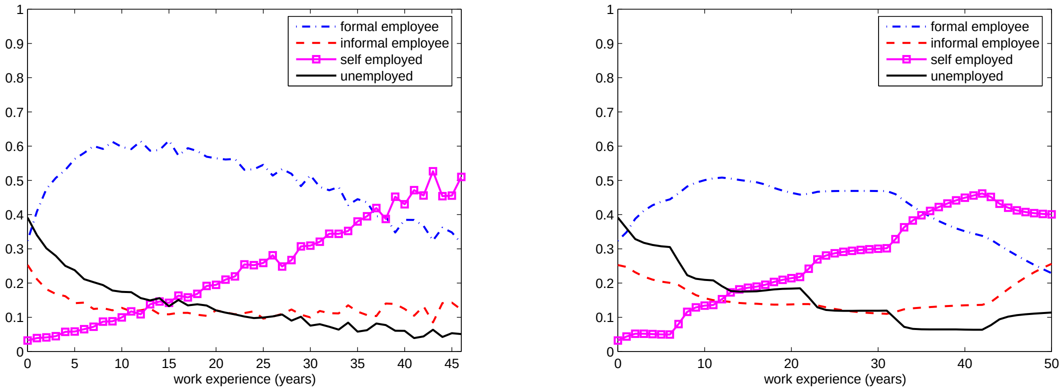
Composition of Workforce - Males, Education 10-11 years



Empirical | Model

FIGURE 6

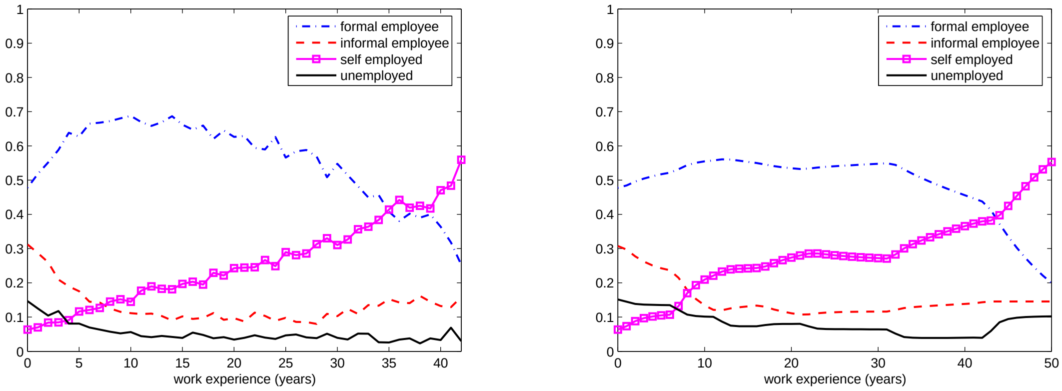
Composition of Workforce - Females, Education 10-11 years



Empirical Model

FIGURE 7

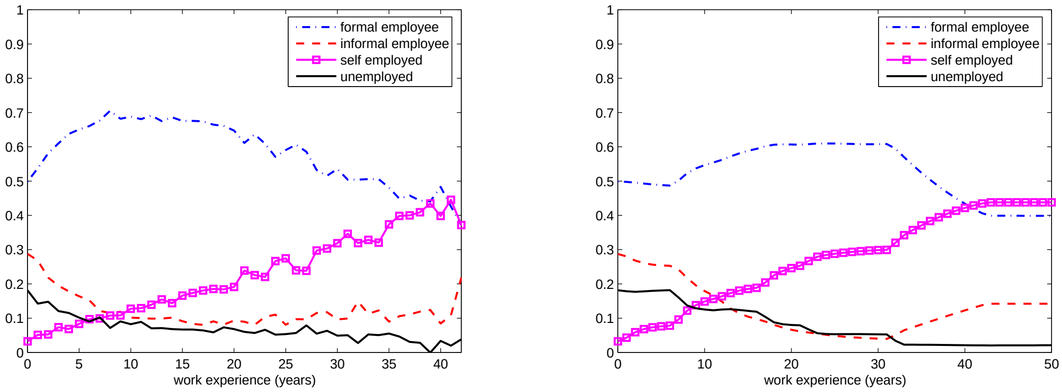
Composition of Workforce - Males, Education 12+ years



Empirical Model

FIGURE 8

Composition of Workforce - Females, Education 12+ years



Empirical Model

FIGURE 9

Estimates of Job Arrival, Job Destruction and Entry into Self Employment Probabilities (Males, Education 0-9 years)

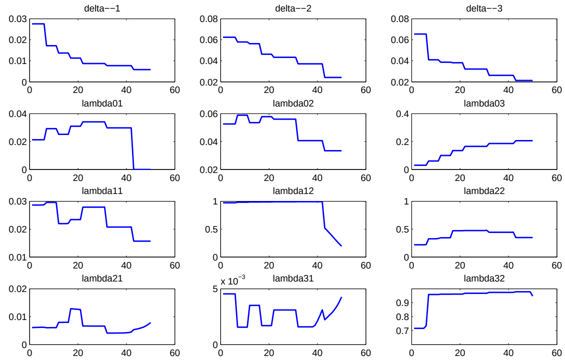


FIGURE 10

Estimates of Job Arrival, Job Destruction and Entry into Self Employment Probabilities (Females, Education 0-9 years)

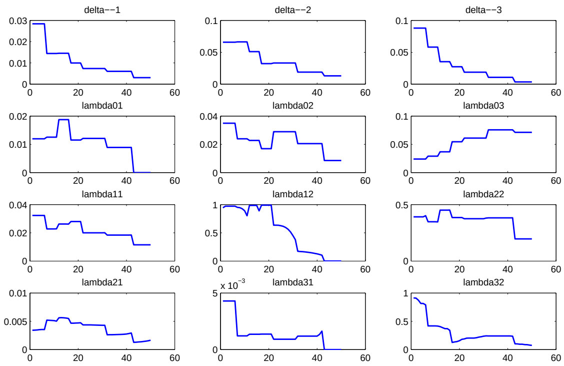


FIGURE 11

Estimates of Job Arrival, Job Destruction and Entry into Self Employment Probabilities (Males, Education 10-11 years)

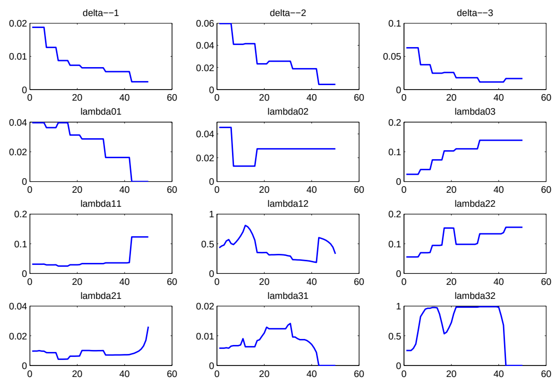


FIGURE 12

Estimates of Job Arrival, Job Destruction and Entry into Self Employment Probabilities (Females, Education 10-11 years)

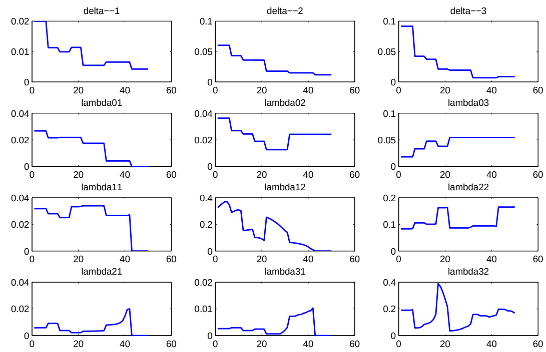


FIGURE 13

Estimates of Job Arrival, Job Destruction and Entry into Self Employment Probabilities (Males, Education 12+ years)

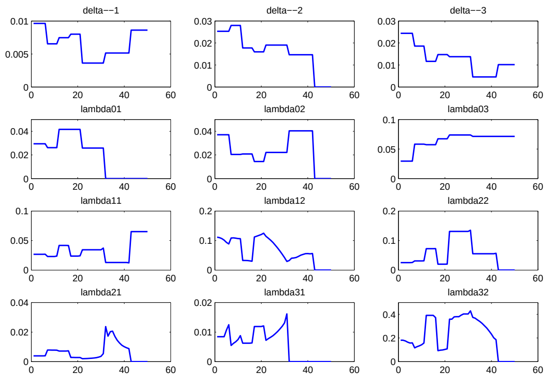


FIGURE 14

Estimates of Job Arrival, Job Destruction and Entry into Self Employment Probabilities (Females, Education 12+ years)

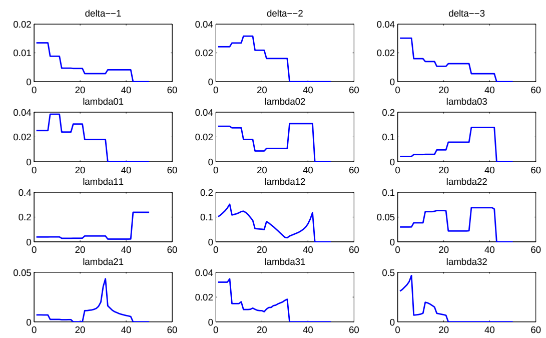


FIGURE 15

Estimate of the Mean Present Value of Workers, by Employment Status - Low Education Males

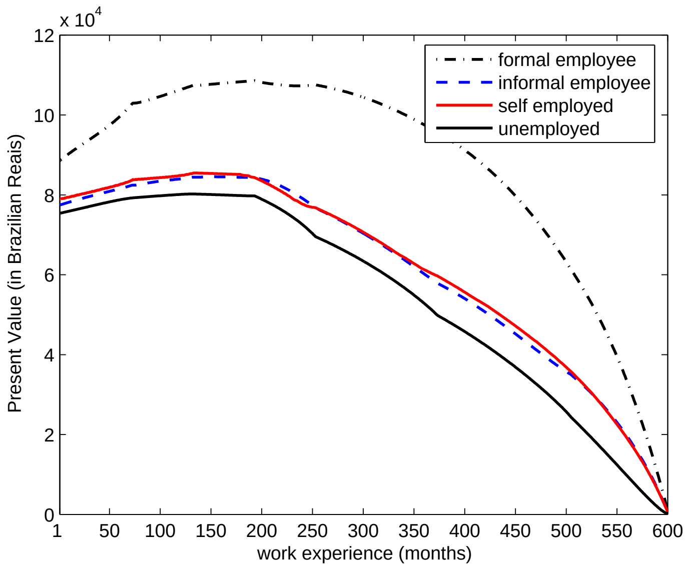
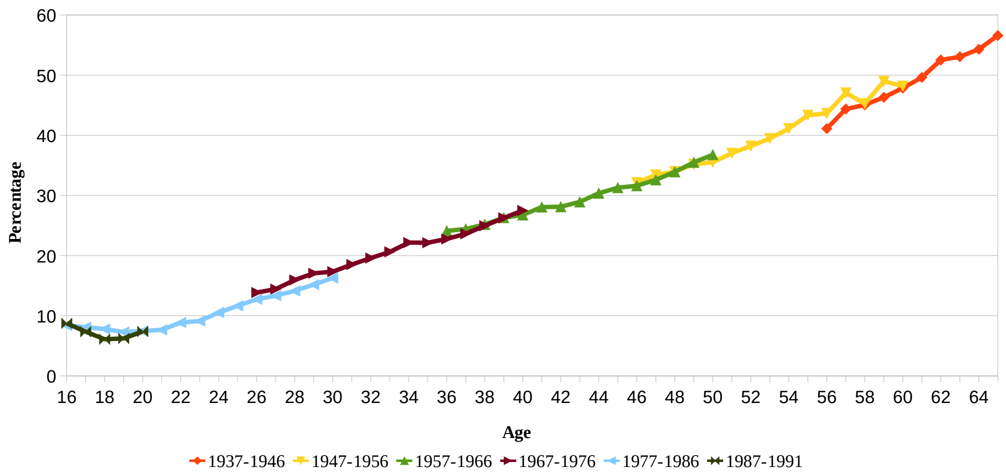


FIGURE 16

Self Employment Rate by Age and Cohorts



Note: Brazilian Labor Force Survey 2002-2007. Figure is constructed using individuals' employment status at the date of their first interview.