Microsimulation analysis of informal labour markets in developing countries

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Declarations

No part of this thesis has been submitted for another degree.

Chapter 1 is co-authored with Dr H. Xavier Jara. Dr Jara suggested the simulation methodology and extensively revised the document. I carried out all estimations and their analysis. The tax-benefit microsimulation model for Ecuador: ECUAMOD was developed within the scope of the SOUTHMOD project. I developed its Colombian counterpart: COLMOD, during my PhD studies. The Colombian model is now hosted at Universidad Externado de Colombia.

Chapters 2 and 3 are exclusively mine.

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Summary

This PhD thesis addresses one of the most pressing problems in developing countries: labour informality. The overall objective of the thesis is to illustrate the capacity of microsimulation techniques to analyse a broad range of topics related to this problem. To highlight the potential of the methodology we pose a motivating question: what are the barriers that informal workers face to becoming formal? Job contact networks and workers' social insurance contributions are analysed alongside other usual suspects such as the lack of human capital. The first chapter proposes a tax-benefit microsimulation exercise for Ecuador and Colombia in which we move informal workers to the formal sector. We found that a considerably high proportion of formalization income gains would be taxed away in both countries. The second chapter presents different behavioural models built on the static tax-benefit model for Colombia and considers labour supply responses and job availability constraints. A simulation exercise of pro-formality policies results in a modest to null effect on the composition of the pool of workers between the formal and informal sectors. Lastly, the third chapter presents an agent-based macroeconomic model with an informal sector that introduces the formation of job contacts on the job as a novel feature. After estimating several of the parameters for the Colombian labour market, our exploratory exercise indicates that a high degree of sectoral homophily in contact networks does not seem to contribute to labour market segmentation because the current propensity to use contacts for job search is not relatively high.

Contents

Introduction 1

References 6

Chapter 1: Financial disincentives to formal employment: evidence from Ecuador and Colombia 7

1.1 Introduction 8

1.2 Literature review 9

1.2.1 Labour informality: definition and causes 9

1.2.2 Labour market informality in Ecuador and Colombia 11

1.2.3 The effects of taxes and benefits on informality 12

1.3 Methodology 14

1.3.1 Definition of informality 14

1.3.2 Data and simulations 15

1.3.3 Simulating transitions from informal to formal work 18

1.3.4 Measuring financial incentives to formal work 20

1.4 Empirical results 23

1.4.1 Tax-benefit instruments in Ecuador and Colombia 23

1.4.2 A portrait of informal employment in Ecuador and Colombia 25

1.4.3 Earnings differentials between sectors 27

1.4.4 Financial disincentives to formal employment 29

1.4.5 Distributional implications of formalization 37

1.4.6 Budgetary implications of formalization 40

1.5 Conclusion 41

1.6 References 44

A.1 Appendix 48

A.1.1 Formalization Tax Rates assuming no change in earnings 50

A.1.2 Incentives to informal work for formal workers 50

Chapter 2: The supply of informal labour in Colombia: a microeconometric approach 52

2.1 Introduction 53

2.2 Labour formality choice 55

2.3 Labour supply models 57
2.3.1 Discrete Choice Labour Supply (DC) 58
2.3.2 Labour supply in Random Utility-Random Opportunity models (RURO) 60
2.3.3 Labour supply and sectoral choice: an extended RURO (RURO-SC) 62
2.3.4 Estimation 63
2.3.5 Simulation 64
2.3.6 Overview 65
2.4 Data and empirical results 66
2.4.1 Data and definitions 66
2.4.2 Estimation assumptions 68
2.4.3 Estimation results 69
2.5 A simulation exercise 75
2.5.1 Simulating changes on education and social insurance contributions 76
2.6 Conclusions 78
2.7 References 80
A.2 Appendix 85
Chapter 3: The role of job contact networks on formal-informal labour dynamics 86
3.1 Introduction 87
3.2 Informality, labour dynamics and job contact networks 89
3.2.1 Equilibrium models of informality 89
3.2.2 Job contact networks and labour markets 91
3.2.3 Agent-based model in labour economics 94
3.3 Informality: some motivating facts for Colombia 96
3.3.1 Data 96
3.3.2 Stylised facts 96
3.4 Methodology 100
3.4.1 The model 101
3.4.2 Estimation 112
3.4.3 Results 117
3.5 Counterfactual exercises 121

3.5.1 Changes in the propensity of use of contacts 121
3.5.2 Changes in the number and duration of connections 124
3.6 Conclusions 126
3.7 References 128
A.3 Appendix 133
A.3.1 Stationarity and Ergodicity 133
A.3.2 Sensitivity of the estimated parameters 136
Conclusion 138

List of Tables

1.1 Determinants of Labour Formality 27

1.2 Mean and Median regression estimates of FTR 36

1.3 Distributional measures for the formalization exercise 38

1.4 Budgetary Effects of different scenarios 40

A1.1 Descriptive statistics for Ecuador and Colombia 48

A1.2. OLS estimates of log hourly wages for formal workers 49

2.1 Descriptive statistics for the estimation sample 67

2.2 Models of Labour Supply 70

A2.1 Wage and participation estimation for DC model 85

3.1 Job contact network use, informality and earnings 100

3.2 Distribution of workers and firms by size and formality status 113

3.3 Fixed parameters and initial conditions 115

3.4 Parameters observed and estimated for the Colombian Economy 118

3.5 Linear probability models of sectoral transitions 123

List of Figures

1.1 Mean share of tax-benefit instruments in household disposable income 24
1.2 Formal worker's tax payments and earnings 25
1.3 Earnings distribution of formal and informal workers 26
1.4 Percentage change in labour income by decile of baseline earnings 28
1.5 Percentage change in labour income by groups 29
1.6 FTR by quintile of baseline earnings in informality 30
1.7 FTR by category of employment 31
1.8 Share of workers by range of FTR 32
1.9 Mean FTRs by gender, education and type of work 34
1.10 Share of workers by range of FTR 35
A1.1 Formalization Tax Rates, assuming no change in earnings 50
A1.2 Share of workers by range of FTR assuming no change in earnings 50
A1.3 Formalization Tax Rates, assuming no change in earnings 51
A1.4 Share of workers by range of FTR assuming no change in earnings 51
2.1 Hours worked fit 72
2.2 Wage and Consumption fit 73
2.3 Indifference curves 73
2.4 Sector and sectoral wage fit 75
2.5 Simulated wage and opportunities changes 76
2.6 Sectoral Movement 78
3.1 Firm and worker informality rates in Colombia 97
3.2 Earnings gap and poverty incidence by occupations 98
3.3 Worker stocks and flows in the Colombian Labour Market 98
3.4 Timing of activities of each month 104
3.5 Estimated and observed moments 119
3.6 Fit of not targeted moments 119
3.7 Job contact networks 120
3.8 Effects of changes in the probability of using contact networks 122

3.9 Effects of changes in the probability of using contact networks 123
3.10 Complementarity between nTypeF and ζ 125
3.11 The effect of changes in nTypeF and ζ on the real economy 125
A.3.1 A.3.1 Mean and 95 CI for the main aggregates of the model 134
A.3.2 Window series for the main aggregates of the model 135
A.3.3 Window series for the moments used for estimation 136
A.3.4 Evaluation of parameter estimates 137

Introduction

This PhD thesis addresses one of the most pressing problems in developing countries: labour informality. Within this broad term we encompass labour activities of low productivity and scale, and out of sight from the government; these features translate into precarious earnings and a lack of the social protection benefits that the law traditionally provides to workers. Informality matters because it affects around half of the workforce in most Latin American economies and it curtails efforts to increase tax revenues and to provide the kind of public goods most developed economies offer to their citizens.

Given the scope of the concept, many definitions are proposed in the literature to identify formal and informal activities in household, firm, and aggregate data. In the thesis we follow the *legalistic view* which characterises formal jobs as those that comply with all legal rules in the labour law of each country (e.g. affiliation to social security, minimum wage, employment protection legislation). Considering the difficulties of identifying compliance with all the rules in the household data that we use, we operationalise this definition using each worker's reported affiliation to the contributory social security system.[1] This approach provides a direct link between informality and the design of tax-benefit systems that we use in the first two chapters.

The overall objective of the thesis is to contribute with a methodological approach – microsimulation – to the analysis of informality in developing countries. This modelling technique allows us to (i) capture population heterogeneity, and (ii) use ex-ante counterfactual simulations (policy experiments) for policy evaluation. In this sense, microsimulation offers the possibility of expanding the scope of research on informality in developing countries, for which cross-sectional microdata is typically available. The three chapters of the thesis could be thought of as case studies that attempt to move the economic study of informality away from the effects of payroll taxes on formal labour demand, and the use of general equilibrium models, which have proven limited in terms of effective policymaking.

[1] Here we focus on the first job of the worker. In our data 6.3% of workers have a second job, 1.7% have a second job and are formal in the first job, and 1.1% have a second job and are formal in both jobs.

The thesis is composed of three interlinked chapters focusing on Colombia, a country that, despite abundant research and policy reforms, has a labour informality rate which is stubbornly high at values ranging from 60 to 65 percent. Additionally, firm informality, measured as firm registration, has been relatively constant over time at around 70 percent.[2] [3] As highlighted in the different chapters of the thesis, informality in Colombia is associated with earnings precariousness and poverty, with formal workers receiving 30 percent higher income than informal workers after controlling for other determinants of earnings, and with poverty incidence 20 percentage points (pp) higher for workers in the informal than in the formal sector.

A motivating question that we try to answer using microsimulations is: what are the barriers that informal workers face to becoming formal? Job contact networks and workers' social insurance contributions are analysed alongside other usual suspects such as the lack of human capital.

The three chapters extensively use publicly available Colombian household data. For two of these datasets, we developed a tax-benefit model for Colombia, COLMOD, which is based on the EUROMOD software and its modelling conventions.[4] The first chapter's tax-benefit microsimulation exercise is of a static nature. The second chapter builds on the static tax-benefit model for Colombia and considers labour supply responses. Lastly, the third chapter departs from the tax-benefit policy analysis and develops an agent-based model (ABM), which is basically a dynamic microsimulation environment for the whole economy.[5] For the latter, we study job contact networks as a potential driver of labour segmentation in Colombia.

The first chapter studies the monetary incentives to engage in formal employment implied by the tax-benefit systems in Ecuador and Colombia. The aim of the chapter is twofold. First, to quantify the financial costs that informal workers incur in the event of entering formality. Second, to assess the effect of a hypothetical scenario in which the economy would be fully formalized. From an

[2] Note that for formal workers the share of social contributions paid with respect to the theoretical level is around 100% implying that on average workers are contributing to social insurance based on their reported earnings.

[3] Despite the fact that the intensive margin of informality (the labour informality rate inside each firm) has been recently studied and found to be important in countries such as Brazil (Ulyssea, 2018), currently there is no firm survey in Colombia that allows us to dig deeper into this issue. The firm data presented is obtained from employers responding to a household survey.

[4] Additional information for the model can be accessed at www.uexternado.edu.co/economia/colmod. This includes external validation and description of the tax-benefit rules.

[5] See Richiardi (2013) for a discussion on the convergence of ABMs and Microsimulation.

individual perspective we quantify the financial cost that each informal worker would incur in the event of entering formality. We build on previous work from Koettl (2013) and Koettl and Weber (2012) which propose a Formalization Tax Rate (FTR) indicator to measure formal work incentives in some Eastern European countries. Considering that this previous literature mainly focuses on compliance with the tax-benefit system and not on earnings and uses hypothetical households, we propose an alternative definition of FTR to account for potential changes in earnings after formalization using real household data. More precisely, in our exercise we estimate the change in earnings of each informal worker that moves to the formal sector based on individual characteristics and we then calculate the share of this change in earnings that is taxed away. Our results show that this share is considerably high, at around 60 and 92 percent on average in Ecuador and Colombia, respectively. This figure is also considerably higher for informal self-employed workers at the bottom of the earnings distribution because of a requirement that workers contribute to social security at least on the basis of the minimum wage in both countries. The results arise even as each worker's counterfactual earnings in the formal sector are higher on average than baseline earnings, with increases in excess of 100 percent for workers in the first decile of the baseline earnings distribution.

The hypothetical scenario of a fully formalized economy allows us to assess the budgetary and distributional implications of formalization. Despite the fact that such an exercise clearly omits general equilibrium effects, it gives us an important picture of the burden of labour informality on poverty, inequality, and the finances of the social protection system. We found important reductions in market income inequality of between 4 and 6 pp in the Gini coefficient resulting from earnings gains at the bottom of the distribution. However, more than three-fifths of the Gini gains are offset by high social contributions for workers entering formality. Moreover, the improvements in the poverty headcount of between 5 and 10pp after moving workers to the formal sector are more than reversed when we take into account the tax-benefit system: poverty is between 2 and 6 pp higher than in the baseline. Given the high levels of informality in Ecuador and Colombia, aggregate revenue from social insurance contributions would increase considerably: around 70 percent in both countries. On the contrary, the increase in tax revenue would be modest, between 1.3 and 5.8 percent, due to the high non-taxable thresholds and deductions from personal expenditures characterising the design of personal income tax in the two countries.

The second chapter seeks to contribute to the methodologies used in the informality literature by introducing different structural labour supply models that allow behavioural simulations at the micro level. In the first part, we present a detailed review of two kinds of models: a discrete choice model (DC) proposed by van Soest (1995) and a Random Utility Random Opportunity model of job choice (RURO), proposed by Aaberge, Dagsvik and Strøm (1995). Whereas the DC assumes full availability of jobs at a fixed wage, the RURO can be thought of as a generalisation of the DC framework in which wages are not fixed and job availability is restricted. Moreover, for the RURO model we present a standard version and an alternative version involving sectoral (formal-informal) choice following Dagsvik and Strøm (2006) and Aaberge and Flood (2013). We present the specificities of estimating the three models using Colombian microdata and the Colombian tax-benefit model.

To illustrate the scope of potential counterfactual simulations, in the second part we focus on the RURO model with occupational choice and analyse the behavioural responses of informal workers to exogenous changes in disposable income, social insurance contributions, and educational achievement. In line with the hypothesis of labour market segmentation, simulation of pro-formality policies results in a modest to null effect on the composition of the pool of workers between the two sectors. For instance, an increase in the share of informal workers with higher education from 14.5 to 67.5 percent increases wages and job availability in the formal sector. However, only 6.5 percent of informal workers are observed to make a transition to formality, implying that there are important unobserved variables determining the availability of formal jobs for informal workers. The analysis does not aim to be representative of the Colombian labour market as we focus on single individuals and omit non-pecuniary differences between sectors. However, the proposed exercise highlights the advantages offered by structural labour supply models to study informal labour markets in the context of developing countries.

The last chapter presents an exploratory exercise which expands a macroeconomic ABM (Lengnick, 2013) to study the relationship between labour informality and the formation of job contacts on the job. The proposed framework could be useful when model intractability at the micro level prevents the analysis of certain phenomena at the macro level. We resort to an existing ABM for three reasons: a) the model allows us to include "general equilibrium" feedback specially arising

from the goods market; b) given that the Lengnick (2013) model is relatively simple yet comprehensive, its recycled use could increase the chances of future implementations; c) most of the relevant literature in informality (Ulyssea, 2018, Meghir et al., 2015, Albrechtet al., 2009) has moved to a general equilibrium approach making the various methodologies more comparable.

The model features a two-market exchange economy in which firms of heterogeneous productivity labelled formal or informal produce a single physical commodity using homogenous labour as input. Households offer labour to firms in exchange for a wage that allows them to buy the physical commodity. Firms and households are fixed in number and only relate to a small network of agents from which they obtain information about current prices or jobs: households and firms are connected to exchange labour and the physical commodity, and households are connected between them to obtain information on job openings. Connections are modified in the search for economic advantages or alternatively if the links between households age and die.

We assume that direct and indirect job search (i.e., using contact networks) are perfect substitutes, and focus on how the propensity of using job contacts affects the informality divide and the aggregate outcomes of the model. We estimate the most important parameters for the production and the labour market of the model using information from Colombian household surveys and find a high degree of sectoral homophily in contact networks: informal and formal workers have on average 70.3 and 81.5 percent of connections in their sectors, respectively. However, the current propensity of use of contacts does not seem to contribute to labour market segmentation: these conditions do not prevent workers from moving between sectors in search of better job opportunities because the observed propensity of using contacts is not relatively high. We also find that marginally increasing the propensity to use contact networks increases the proportion of jobs found through contacts, although, there are diminishing returns to using contacts because of congestion in the use of networks.

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Chapter 1: Financial disincentives to formal employment: evidence from Ecuador and Colombia[1]

(Co-authored with Xavier Jara)

Abstract

Despite recent formalization policies, labour informality remains high in Latin American economies. In this paper we explore the effect of the tax-benefit system on the supply of informal labour. To do so, we quantify the financial cost informal workers would incur in the event of entering formality. We use representative microdata from Ecuador and Colombia, together with detailed tax-benefit models, and simulate transitions to the formal sector for all workers observed in informality in the data, where informality is defined as non-affiliation to social security. Our analysis takes into account potential earnings gains on entry to formality and redefines the formalization tax rate as the proportion of the change in earnings that will be taxed away in the form of increased taxes and social insurance contributions or reduced cash transfers when a worker enters formality. Our results point to strikingly high formalization tax rates, with 60 and 92 percent of worker's change inearnings taxed away on average in Ecuador and Colombia, respectively. Costs are particularly high for self-employed informal workers at the bottom of the earnings distribution. The results are mainly driven by the design of social insurance contribution, and in particular, the requirement that workers contribute to social security at least on the basis of the minimum wage in both countries.

JEL: J42, H22, H55

Keywords: Informality, microsimulation, formalization tax rate.

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[1] The results presented here are based on ECUAMOD v1.4 and COLMOD v1.1. ECUAMOD is developed, maintained and managed by UNU-WIDER in collaboration with the EUROMOD team at ISER (University of Essex), SASPRI (Southern African Social Policy Research Institute) and local partners in selected developing countries (Ethiopia, Ghana, Mozambique, Tanzania, Zambia, Ecuador and Vietnam) in the scope of the SOUTHMOD project. The local partner for ECUAMOD is Instituto de Altos Estudios Nacionales (IAEN). We are indebted to the many people who have contributed to the development of SOUTHMOD and ECUAMOD. COLMOD is developed, maintained, and managed by the Faculty of Economics at Universidad Externado de Colombia. The authors are grateful to participants at the Public Economics Seminar at KU Leuven, the Euromod Research Group at Essex and the UNU-WIDER microsimulation conferences at Helsinki and Quito. We are indebted to Bart Capeau and Olivier Bargain. The authors are responsible for all remaining shortcomings.

1.1 Introduction

In Latin American economies, characterised by highly concentrated capital income and limited social protection, labour income represents the main alternative for families to overcome poverty. A particular feature of labour markets in the region continues to prompt interest among academics and policy makers, namely, informality, a concept that has evolved over time due to the complexity of its definition. Over recent years, the region has experienced important economic growth and a number of formalization policies have been introduced in different countries. However, informality remains prevalent and further research is needed to analyse its underlying causes.

The coexistence of two very dissimilar productive sectors, formal and informal, is usually studied within two perspectives: exclusion and exit (Perry et al. 2007). The former assumes that being formal is expensive for small companies and workers whose productivity is low relative to the burden of regulation and taxes; therefore, they are excluded from the formal sector (de Soto, 1989). The latter suggests that firms and workers optimally choose whether to be formal and contribute to taxes and social insurance or not, having both options available (Maloney, 1999).

Under these two perspectives, the role played by taxes, and more generally by the tax-benefit system, is central to the discussion. The aim of this paper is, therefore, to quantify the cost that informal workers would incur in the event of entering formality. For this, we make use of household microdata from Ecuador and Colombia and simulate transitions from informal to formal employment by means of multi-country tax-benefit microsimulation techniques in order to elucidate the financial disincentives to formality embedded in the tax-benefit system. We take into account potential income gains of informal workers when entering the formal sector, as well as compliance with minimum wage legislation in place in each country. As such, we revise the concept of formalization tax rates and redefine it as the proportion of the change in earnings that would be taxed away in the form of increased taxes and social insurance contributions or reduced cash transfers when a worker enters formality.

Our analysis provides a number of interesting findings. First, formalization costs are very high in Ecuador and Colombia, and would outweigh most of the potential monetary gains on entry to formal employment. On average, around 60 and 92 percent of workers' change in earnings in

formality would be taxed away in the form of increased taxes and social insurance contributions in Ecuador and Colombia respectively. Second, the high formalization costs are mainly driven by the payment of social insurance contributions, with income taxes playing only a marginal role due to high non-taxable thresholds and deductions from personal expenditures applied to taxable income. Third, formalization tax rates vary greatly between employees and self-employed workers in the informal sector and are particularly high at the bottom of the self-employed earnings distribution. Fourth, assuming informal workers would face similar earnings as their formal counterparts upon entry to formality, a full formalization of informal workers would reduce income inequality in both countries and would increase total revenue from social insurance contributions by around 71 percent. However, the largest burden of the increase in revenue would be borne by workers.

The contribution of this paper to the literature is twofold. First, to the best of our knowledge, our analysis represents the first attempt to give a comprehensive estimate of the financial disincentives to formal employment based on microdata from Latin American countries thanks to the recent development of detailed tax-benefit microsimulation models. Previous studies have mainly focused on European countries, and used models based on hypothetical households rather than microdata. Second, we consider the fact that informal workers would not necessarily face the same earnings on entry to the formal sector, and this has implications for the measurement of formalization tax rates.

The paper is structured as follows. Section 1.2 discusses the definition of informality and reviews the literature on its causes, and in particular the role of tax and benefit systems. Section 1.3 presents the methodology of the Ecuadorian and Colombian microsimulation models and the simulation exercise. Section 1.4 presents a brief quantitative overview of informality in Colombia and Ecuador and focuses on the estimations of the cost of formalization for informal workers. The last section concludes with some recommendations.

1.2 Literature review

1.2.1 Labour informality: definition and causes

Informality is a complex concept that has been defined in multiple ways. Originally, the term referred to small-scale economic activities hidden from government supervision; often denoted as

the "underground", "unrecorded", "non-protected" or "grey" sector of the economy.[2] The concept of informality first appeared in an International Labour Organization (1972) publication describing the employment situation in Kenya (Guerguil, 1988).

The complexity of defining informality is reflected in the existence of different approaches to its measurement. Empirical studies have mainly considered two alternatives: the productivity view and the legalistic view. The *productivity view* defines informality according to the size of the establishment where the individual works (hereinafter ES). Following the ILO and the Delhi Group on Informal Sector Statistics, small firms (of five or fewer workers) are considered to be of low productivity and therefore part of the informal sector. The *legalistic view* characterises formal jobs as those that comply with all legal rules in the labour law of each country (e.g. affiliation to social security, minimum wage, employment protection legislation). Considering the difficulties of identifying compliance with all the rules, this view is operationalised using each worker's reported affiliation to the contributory social security system (hereinafter SS). One less frequent and simplistic view considers as informal solely self-employed workers (hereinafter SE). As Henley et al., (2008) pointed out, the definition employed matters a lot as they are not observationally equivalent.

In addition to the lack of consensus in its definition, the causes of informality are also a matter of dispute. In its origins, it has been considered as the result of low productivity and high labour market regulations. This mix excludes certain workers from the formal sector therefore creating a segmented labour market. In that sense, early economic analyses of informality have been based on the insights of the two-sector model of Harris and Todaro (1970) popularised for the informality literature by de Soto's (1989) work, which argued that regulations hamper informal firms from formalizing. More recent literature moves beyond this exclusion view by pointing out that workers and firms choose optimally to be in one or another sector, by analysing expected returns and costs, considering taxes and social contributions to be made, low government's enforcement capacity, and availability of non-contributory social security and conditional cash transfer (CCT) programmes. Informality is, therefore, the result of a comparative advantage for a segment of activities or

[2] Such activities were mainly focused on creating employment rather than profits.

workers. The pioneer work in this regard is that of Portes et al., (1989), which highlights, among others, that informality is not "solely a province of the poor".

1.2.2 Labour market informality in Ecuador and Colombia

In reference to Ecuador and Colombia, the literature has studied informality not only from the perspective of workers but also from firms. This section briefly summarises some relevant studies analysing the determinants of informality in these countries, highlighting the different definitions of informality used.

The first analysis of informality for Ecuador dates back to Klein and Tokman (1993). They employed an OECD survey of micro and small enterprises in Ecuador and Jamaica to explore the determinants of compliance with regulations. They found that activity sector was not an important determinant, but firm size and location were important predictors of formality, measured as firm registration. Another study involving a survey of firms in Ecuador is that of Medveded and Oviedo (2015) which explores the relation between informality (measured as firm compliance with a set of regulations) and profits. Using data on compliance they found a strong positive relation indicating that formalization allows for firm growth and higher profits.

Regarding studies from the workers' perspective, Vega (2017) constructs transition matrices between formal and informal (ES and SS) sectors, and out of the labour force for Ecuador to assess the level of mobility across sectors. She makes use of multinomial logit models to analyse determinants of transitions between these states and finds a high level of mobility, with income differences being one possible source of movement from the informal to the formal sector. Additionally, it is found that movements towards formality increase with education but decrease with age. Moreover, Canelas (2014) analyses the effect of minimum wage increases on informal and formal employment (ES, SS, and SE) for Ecuador, employing a panel of provinces and finding no effects on formal employment or wages in the formal sector, possibly because of the high level of non-compliance with minimum wage legislation in the country.

For Colombia, informality has also been considered from the perspective of workers and firms. Kugler (2004) uses microdata from household surveys to analyse the effect of a reduction in firing costs on formal (ES and SS) worker transitions in and out of employment. The study shows that

relative to informal workers (not covered by the reform) formal turnover increased, especially for younger educated workers. Updating her previous work but using a panel of formal firms for the period 1982-1996, Kugler and Kugler (2009) find that a 10 percent increase in payroll taxes decreased wages by up to 2.3 percent (pass-through effect) and employment up to 5 percent.

On the other hand, Mondragón-Vélez et al., (2010) find that a 10 percent increase in the ratio of minimum wage to each city's median wage increases the probability of a worker being informal by 1.1 pp. Moreover, a 10 percent increase in non-wage costs relative to each workers income increases the probability of being informal (ES) by 8 pp. These results are statistically significant but dramatically change with the alternative definition of informality as contributory health. Lastly, García (2011) estimates determinants of the labour informality rate at the city level. Using data for 10 Colombian cities across 16 years, he finds that higher education and industry participation in value-added reduces informality (ES). Furthermore, enforcement, measured via government expenditure on compliance, reduces the informal (SS) sector, but government size increases it.

1.2.3 The effects of taxes and benefits on informality

Previous research on labour informality has mainly focused on the effect of specific cash transfer programmes, instead of assessing the effect of the tax-benefit system as a whole. From a theoretical point of view, assuming workers are free to move between sectors, if CCT are too low to live on and are not compatible with a formal job or, alternatively, if benefits from a formal job are not high enough, a worker could decide to work in the informal sector.

Empirical findings of the effects of CCT on informality are recent and have been inconclusive. For instance, Garganta and Gasparini (2015), using a rotating panel find that *Asignación universal por hijo*, a CCT programme in Argentina, creates disincentives for labour formality (SS). Ribas and Soares (2011) create a panel of neighbourhoods from the Brazilian Household Survey and find that an increase of 1 percent in coverage of *Bolsa Familia* (a CCT in Brazil) leads to a switch to the informal sector (SS and SE) of 0.13 percent. De Brauw et al., (2013) use a panel of households and find that the Brazilian programme contributed to a significant movement of workers from the formal sector to the informal sector (SS). On the other hand, Azuara and Marinescu (2013) employ a panel of municipalities and find that *Oportunidades* (a CCT in Mexico) did not increase labour informality (SE and SS). Neves and Leite (2014) use a discontinuity in *Bolsa Familia's* eligibility

rules regarding children's ages to estimate the effect of the programme on informality and find that it did not affect the occupational choice between formal and informal (SS) of Brazilian households. In the case of Colombia most evidence points to a negative effect of social programmes on informality. For instance, Núñez (2002) uses a household survey to calculate the effect of each worker's marginal income tax rate (constructed using reported income) on the probability of being informal (ES), defined according to firm size, and finds a positive and significant effect. Camacho et al., (2014) analyse the effects of a programme that determines eligibility for subsidised health care on labour informality (SS). Carrying out an analysis at the municipal level, they find that informal employment would be 4 pp higher after the introduction of the programme.

Using data on *Familias en Accion*, a CCT programme aimed to increase human capital accumulation in Colombia, Ospina and Saavedra (2013) find that being beneficiary increases informality (SS, SE, ES). Finally, Farné et al., (2016) employ a longitudinal household survey to estimate the effects of several CCT programmes and non-contributory health care on labour participation and informality ES. They use difference-in-difference estimators after propensity score matching and find no important effects on participation but important effects of programmes such as subsidised health care and *Familias en Accion* on labour informality.

For Ecuador, evidence of the effect of tax-benefit systems on informality is scarcer. Wong (2015) analyses the labour market effects of a formalization programme for domestic workers in 2010. She estimates the average treatment effect on-the-treated after propensity score matching for wages and hours worked using data from the National Survey on Employment, Unemployment, and Underemployment (ENEMDU in Spanish). While the programme increased social security coverage from 10 percent in 2006 to 33 percent in 2012, it also reduced both wages and hours worked.

Important efforts to quantify the financial disincentives embedded in the tax-benefit system and faced by informal workers are the studies by Koettl and Weber (2012), Koettl (2013) and Weber (2015); these are in line with the approach taken in this paper. These authors use an OECD tax-benefit model to quantify the tax wedge for transitions to formality, based on hypothetical households. Contrasting experiences of two transition economies (Bulgaria and Romania) with two high-income economies (Australia and the USA), they find that, for transition economies formalization tax rates (defined as the proportion of earnings in the informal sector that would be taxed away after entry to formality) are as high as 70 percent for lower wages

(10 percent for the average) whereas the highest formalization tax rate for higher-income economies is 40 percent which applies to incomes that are about 45 percent of the average.

Improving on the last two studies, our paper uses representative household microdata together with microsimulation models to analyse the distribution of financial disincentives to formality at the population level in Ecuador and Colombia. Moreover, we propose a definition of formalization tax rates which accounts for potential changes on earnings upon entry to formal employment, as described in the following sections.

1.3 Methodology

Our approach to assess the effect of the tax and benefit system on incentives to enter formality makes use of detailed tax and benefit microsimulation models combining country-specific policy rules with nationally representative household microdata to estimate, for each informal worker in the data, the proportion of income that will be lost as a result of higher taxes, higher social insurance contributions and lower benefits after an eventual transition to formal employment.

Our analysis takes into account that these transitions might involve a change in earnings and we therefore impute counterfactual earnings for each worker in the event of a transition to formality. Notice that benefits in both countries (mainly conditional cash transfers) are proxy-means tested. This implies that we are not able to simulate how each worker's household is affected in the medium run if the formalization exercise translates into changes in the score used in each country to assign benefits. This means that our estimates of the tax-benefit burden of formalization have to be considered as a lower bound of the actual ones given that formalization could potentially reduce benefits received.

We start this section with a brief discussion of the definition of informality used in this paper. Then, we present the data and tax-benefit microsimulation models used in the analysis. We describe our approach to simulate transitions into formal employment and finally we present our indicators to measure financial incentives to formal employment.

1.3.1 Definition of informality

Our paper follows the *legalistic view* proposed in the literature and defines informality in terms of non-affiliation to the contributory social security system. This definition is particularly suited to

our analysis because it is directly linked with the effect the tax-benefit system would have in the event of a transition to the formal sector. More precisely, we make use of the detailed information available in the household survey data for each worker about affiliation to social security and define as informal workers those reporting non-affiliation.

In Ecuador, effective affiliation requires formal registration at the Ecuadorean Institute of Social Security. Therefore, we consider formal workers those individuals who report being affiliated to social security in the data. Affiliation offers entitlement to, among others, health and pension insurance, severance pay, and disability and occupational risk insurance. In Colombia, effective affiliation is achieved first by registering with a Health Promoting Entity (EPS in Spanish) and a pension fund, and second by a monthly payment of social insurance contributions (SICs). We consider formal workers those who declare making pension contributions to a pension fund in the survey; therefore, non-contributing registered workers are considered informal. Affiliation offers entitlement to, among others, health insurance, sickness, maternity, and paternity leave payments and an old-age pension under some conditions.[3]

It is important to note that, for the purpose of our simulations, when a worker is defined as informal, we assume that the person does not pay SICs or personal income tax. After formalization, we assume both payments are made and calculate SICs and income tax liabilities for each worker entering formal employment with our microsimulation models, as discussed in the following sections.

1.3.2 Data and simulations

Data. Our analysis is based on representative household survey data from Ecuador and Colombia. Data from Ecuador come from the National Survey of Income and Expenditures of Urban and Rural Households (Encuesta Nacional de Ingresos y Gastos de Hogares Urbanos y Rurales, ENIGHUR) 2011-2012. Data from Colombia come from the Quality of Life National Survey for 2014 (Encuesta Nacional de Calidad de Vida, ENCV). The surveys contain detailed information on employment, earnings, income from different sources and expenditures, as well as household and personal characteristics needed for tax-benefit simulations. Most importantly, both surveys contain

[3] In Colombia those not contributing to social security are covered by a subsidised health insurance with the same benefits as the contributory scheme.

detailed information about affiliation to contributory social security, which we use to define informal workers in our analysis. Income concepts have been harmonized in both datasets with the purpose of cross-country analysis (see Jara et al., 2019; Rodriguez, 2019). The sample for our simulations contains 153,341 individuals for Ecuador and 67,332 individuals for Colombia.

Tax-benefit simulations. Our study makes use of the recently developed tax-benefit microsimulation models: ECUAMOD for Ecuador, and COLMOD for Colombia. Both models combine detailed country-specific coded policy rules with microdata in order to simulate direct taxes, social insurance contributions and cash transfers for the household population of Ecuador and Colombia. The models have been implemented under a common modelling language using the EUROMOD platform, to ensure comparability of tax-benefit policy simulations.[4] Both models are static in the sense that tax-benefit simulations abstract from behavioural reactions of individuals and no adjustments are made for changes in the population composition over time. Simulated income components obtained with ECUAMOD and COLMOD have been validated against external statistics (Jara et al., 2019, Rodriguez et al., 2018).

Our analysis takes 2014 policies (as on June 30th) in Ecuador and Colombia as the starting point. In the case of Ecuador, market incomes and non-simulated tax-benefit variables in the data are adjusted to 2014 levels using source-specific updating factors (Jara et al., 2019). In what follows, we present a brief discussion of the main income components simulated in our models. For detailed information see Jara et al., (2019) and Rodriguez et al., (2018).

In both countries, employee and self-employed SICs are simulated for formal workers, that is, individuals who report affiliation (contribution in Colombia) to social security in the survey. Some differences in the design of SICs between Ecuador and Colombia can be highlighted. First, all self-employed workers are liable to pay SICs in Colombia, whereas payment is voluntary for this group in Ecuador. Second, the contribution base for the self-employed corresponds to all self-employment income in Ecuador, whereas only 40 percent of it is considered in Colombia. In Ecuador, employee contribution rates vary between 9.45 percent and 11.45 percent depending on the sector of work, whereas the self-employed contribute at a rate of 20.5 percent. In Colombia, contribution rates for

[4] EUROMOD is the tax-benefit microsimulation model for the European Union. For more information see Sutherland and Figari (2013).

employees are between 8 percent and 10 percent, and 28.5 percent for the self-employed. Finally, a minimum contribution equal to the rates applied to the minimum wage applies for the self-employed in Ecuador and to all workers in Colombia. In Ecuador, a minimum contribution of 9.45 percent or 11.45 percent of the minimum wage applies to full-time employees; part-time employees pay a minimum contribution based on a proportion of the minimum wage according to the number of days they work.

Baseline simulation results from ECUAMOD and COLMOD, as well as previous studies based on these models have simulated personal income tax under the assumption of full compliance (Jara et al., 2019, Rodriguez 2019, Bargain et al., 2017, Jara and Varela 2017). Our study departs from this assumption and simulates personal income tax only for those individuals reporting affiliation to social security in the survey. This assumption is made with the aim of assessing the effects of personal income tax when an individual enters the formal sector. However, it is important to note that this might overestimate the financial cost of formalization as individuals not affiliated to social security might already be paying taxes, particularly so in Ecuador, where the self-employed can opt for affiliation on a voluntary basis but are required to file income tax.[5] In terms of design, in both countries, personal income tax is characterised by the presence of deductions from personal expenditures. In Ecuador the tax schedule is formed of nine bands with rates from 0 to 35 percent, whereas in Colombia two alternative tax regimes co-existed in 2014 in addition to the standard tax regime, with different bands applying to each regime and marginal rates between 0 and 33 percent.

In terms of benefits, our models simulate the main cash transfers available in the two countries: *Bono de Desarrollo Humano* and *Bono Joaquin Gallegos Lara* in Ecuador and *Familias en acción* and *Colombia Mayor* in Colombia. These programmes are proxy means-tested CCT that do not depend on formality status, with the minor exception of the elderly and disabled in Ecuador. Finally, tax-benefit instruments, which cannot be simulated in our models due to data limitations, are taken directly from the data. This is the case of contributory public pensions, which cannot be

[5] In practice, however, we would expect only a marginal effect of personal income tax on financial incentives to formality. This is the case because of two main factors associated with the design of personal income tax in Latin American countries. First, the non-taxable threshold is rather high in most Latin American countries. It represents 2.54 times and 4.17 times the annualised minimum wage in Ecuador and Colombia, respectively. Second, deductions from personal expenditures can be made from taxable income. Therefore, most informal workers, who are usually low-earners, would not be liable to pay income tax after formalization, as shown in our results.

simulated given the lack of information on contribution records in the surveys. Non-simulated instruments also include disability benefits, severance payments, and property and motor vehicle taxes, among others. Besides contributory pensions, all other non-simulated instruments represent a minor part of tax-benefit systems in Ecuador and Colombia.

1.3.3 Simulating transitions from informal to formal work

Our strategy to quantify the financial cost of formalization consists of moving informal workers in the data into the formal sector and comparing their household disposable income before and after the transition. The effects of a transition to formal employment are simulated for all those currently in work and reporting non-affiliation to social security in the data (that is, informal workers), aged 18-60, to exclude those in mandatory education or retirement. Table A1 in the Appendix presents the characteristics of the samples in each country.

Importantly, transitioning to formal employment might not only entail starting to contribute to social security and being subject to personal income tax, at the same level of earnings. It is quite likely that the earnings a worker would receive when moving from informal to formal employment would change. From the exclusion point of view, the segmentation of the labour market implies that workers in the formal sector face higher wages. This is a result of labour demand rationing due to the burden of legislation, especially minimum wage and non-wage costs for formal activities. On the other hand, from the exit perspective, a worker is formal/informal because there is a comparative advantage to being in that specific sector. Therefore, allocating the person in the alternative sector would possibly represent a disadvantage given the worker's characteristics.

More formally, our approach to simulating transitions from informal to formal employment proceeds as follows. First, household disposable income is calculated for all informal workers in the data before any transition takes place. Then, for each informal worker in the household, we impose affiliation to social security and estimate counterfactual earnings under their new status of formal workers. Lastly, with our tax-benefit models, we simulate the amount of SICs and personal income tax they would be liable to pay, as well as their corresponding household disposable income under formalization. In case there is more than one informal worker in the household, we simulate transitions to formal employment for each of them separately assuming that the status of any other informal workers remains unchanged.

Accounting for earnings differentials. We use a simple strategy to account for potential changes in earnings from moving to formality. The strategy consists of estimating log hourly earnings for formal workers to predict earnings for informal workers based on their characteristics and the estimated coefficients in the regression. More formally, consider a Mincer equation for formal workers:

$$\log(w_f) = \alpha_f + X_f'\beta_f + Z_f'\delta_f + \varepsilon_f \quad (1)$$

where $\log(w_f)$ represents the log of hourly earnings of workers in the formal sector (sector f), X_f a vector of worker attributes and Z_f is a vector of job attributes, and ε_f is an idiosyncratic error term. The estimated parameters of this regression $(\hat{\alpha}_f, \hat{\beta}_f, \hat{\delta}_f)$ are used together with the vector of attributes of informal workers to predict the earnings they would face in the formal sector.

We use a large set of regressors, including observable demographic and job attributes for each worker, which we assume sufficient to determine unbiased hourly earnings estimates in the formal sector. Personal attributes include dummies for age groups, education, gender, rural area, region, and ethnicity. Job attributes include work history (in years) and dummies for industry and occupation. Ideally, one would estimate this equation separately for employees and self-employed. However, there are only a few formal self-employed observations in our sample making counterfactual earnings for this group unreliable. Therefore, we pool employees and self-employed but include dummies for this category. If one is willing to assume some sorting of workers into each sector, this simple counterfactual exercise provides an upper bound of the income of informal workers in the formal sector, that is, without the penalty of being in a disadvantaged sector.

An alternatively to the strategy described above would be to estimate a selection correction model *à la Heckman,* which has been applied to the formal/informal sector setting in very few papers (Marcouiller et al., 1997; Carneiro and Henley, 2002; Pratap and Quintin, 2006). Under this approach, a sector selection model is estimated in a first-stage regression, and then a correction term is included in the log hourly earnings equation in the second-stage to account for potential selection. We applied this second approach to our data but favoured the simpler model for two main reasons. First, previous literature has found contrasting evidence on the sign of the estimated parameter for

the correction term in the second stage equation.[6] Our own estimates are in line with the contrasting evidence. The sign depends on the sample used with large difference between employees and self-employed in both countries. When combining the two groups the coefficient becomes statistically insignificant. This implies that instead of a comparative advantage there could be a penalty of being in the formal sector for some workers, which is inconsistent with the underlying assumption of free movement between sectors in the model. Second, we found that counterfactual earnings are extremely sensitive to the set of exclusion variables employed and, admittedly, is difficult to come up with variables that exclusively affect the probability of being in the formal sector but do not affect earnings.

Minimum wage enforcement. An important aspect of formalization relates to the enforcement of minimum wage legislation. By law, formal workers are required to be paid no less than the minimum wage in each country. In 2014, the national minimum wage was set at USD 340 per month in Ecuador and COP$616.027 in Colombia.[7] Our analysis considers the enforcement of the minimum wage to provide an idea of its effect on financial incentives to formalization. More precisely, we first predict earnings for informal workers as described in the previous section. Then, in case a worker's predicted hourly earnings fall below the threshold in each country, we apply the hourly minimum wage.[8]

1.3.4 Measuring financial incentives to formal work

There is only limited research analysing the financial incentives to formalization embedded in tax-benefit systems (Koettl 2013; Koettl and Weber 2012; Weber 2015). Previous studies have mainly used hypothetical data to measure the burden of formalization created by the tax-benefit system and for this reason they have assumed no change in earnings when moving from one sector to the other.

[6] Yet the implications are rarely discussed. The only exception is that of Pratap and Quintin (2006).

[7] $USD 326. (exchange rate of 20/June/2014)

[8] In both countries the monthly minimum wage is related to full time (48 hours per week in Colombia and 40 hours in Ecuador). Less than full time hours of work are paid proportionally to the minimum wage. Although the majority of workers in our sample work full time, we account for different time regimes by using hourly minimum wages to not overestimate counterfactual earnings.

Koettl and Weber (2012) introduce the concept of Formalization Tax Rates (FTR) defined as the proportion of earnings in the informal sector that would be taxed away after entry to formality. More formally, FTR of individual i is defined as:

$$\mathrm{FTR}_i = \frac{Y^0_{h,i} - Y^1_{h,i}}{w_i}, \tag{2}$$

where w_i represents worker i's earnings in the informal sector and $y_{h,i}$ represents household disposable income for worker i. The superscripts 0 and 1 represent time, that is, before and after simulated formalization takes place, respectively. Koettl and Weber (2012) assume that the employer has a very strong bargaining position or alternatively that the labour supply curve is infinitely inelastic. This implies that any worker must generate the same total labour cost to the employer in the formal or informal sectors and consequently, the entire formalization cost is assumed by the formalizing worker.

However, as stated by the authors, the fixed earnings assumption is not supported by the evidence, with most studies indicating the existence of an earnings gap between the two sectors (see for instance Figure 1.3). This assumption could have limited a wider use of the FTR indicator in the informality literature. In that sense, our measure of formalization costs departs from that of Koettl and Weber (2012) and draws from the literature on work incentives to account for potential changes in earnings following a transition between the informal and formal sector. In particular, we redefine FTRs as the proportion of the change in earnings that would be taxed away in the form of increased taxes and social insurance contributions or reduced cash transfers when a worker enters formality. More formally, we define the FTR of individual i by:

$$\mathrm{FTR}_i = \begin{cases} \left(1 - \dfrac{y^1_{h,i} - y^0_{h,i}}{w^1_i - w^0_i}\right) & \text{if } w^1_i > w^0_i \\ -\left(1 - \dfrac{y^1_{h,i} - y^0_{h,i}}{w^1_i - w^0_i}\right) & \text{if } w^1_i < w^0_i \end{cases} \tag{3}$$

where w_i represents labour earnings of worker i and $y_{h,i}$ represents disposable income of household h, to which worker i belongs. The superscripts 0 and 1 represent the worker states: 1 represents the situation in which worker i is in the informal sector, and 0 the situation where she is in the formal sector. As previously mentioned, in the case that there are multiple informal workers in the

household, transitions to formal employment are simulated for each of them separately, assuming the situation of other informal workers in the household remains unchanged.

In general, we would expect FTR values to range between 0 and 100 percent with higher FTRs representing higher financial disincentives generated by the tax and benefit system to enter formal work. For example, assuming that following a transition to formal employment earnings would increase, an FTR equal to 80 percent would indicates that 80 percent of the change in earnings would be taxed away because of increased SICs and tax payments or reduced cash transfers. In the case of a negative change in earnings (that is, a decrease in earnings following entry into formality), a sign correction is applied to preserve the correct direction of incentives.

As highlighted by Jara and Tumino (2013) for the case of marginal effective tax rates, some features of the tax-benefit system could lead to values of FTRs outside the range of 0-100 percent. An FTR above 100 percent could be observed if, facing earnings increases upon formalization, changes in household disposable income are negative, for instance due to the loss of an important benefit entitlement or to a burdensome tax. On the other hand, a negative FTRs implies that the tax-benefit system provides financial incentives to enter formal employment for example by means of additional benefits after formalization. In our analysis, in order to prevent mean FTRs being affected by such "outliers" we focus our analysis on workers earning more than US$ 1 in Ecuador and COP$10.000 in Colombia per month and exclude from our calculations FTRs above the 99th and below the 1st percentiles of the distribution.[9]

The contribution of different tax-benefit instruments to FTR can be analysed by decomposing the indicator. In particular, household disposable income can be expressed as the sum of market income ($o_{h,i}$) plus benefits and pensions (b_i), minus taxes (t_i) and SIC (s_i):

$$FTR_i = \pm\left(1 - \frac{o^1_{h,i} + b^1_{h,i} - t^1_{h,i} - s^1_{h,i} - \left(o^0_{h,i} + b^0_{h,i} - t^0_{h,i} - s^0_{h,i}\right)}{w^1_i - w^0_i}\right)$$

Following a transition to the formal sector, the only change assumed in household market income ($o_{h,i}$) is that of labour income, therefore necessarily $\Delta o_{h,i} = \Delta w_i$, allowing us to decompose the FTR into each of its components. In the case of an increase in earnings after formalization we have:[10]

[9]USD$ 5.3 (exchange rate of 20 June 2014)

[10] In the case of $w^1_i < w^0_i$ $FTR_i = \left(\frac{\Delta b_{h,i}}{\Delta w_i}\right) + \left(-\frac{\Delta t_{h,i}}{\Delta w_i}\right) + \left(-\frac{\Delta s_{h,i}}{\Delta w_i}\right) = FTR^b_i + FTR^t_i + FTR^s_i$

$$FTR_i = \left(-\frac{\Delta b_{h,i}}{\Delta w_i}\right) + \left(\frac{\Delta t_{h,i}}{\Delta w_i}\right) + \left(\frac{\Delta s_{h,i}}{\Delta w_i}\right) = FTR_i^b + FTR_i^t + FTR_i^s \quad \text{if} \quad w_i^1 > w_i^0 \tag{4}$$

Notice that our definition of FTR is conceptually different from Koettl and Weber (2012). Our measure of formalization costs assumes there are earnings changes and computes a marginal tax rate over this change. Koettl and Weber (2012) assume earnings are fixed and compute an average tax rate. The two indicators are not comparable and therefore we focus on the proposed definition and present results for Koettl and Weber's (2012) definition in appendix A1 and briefly discuss the findings in the next section.

1.4 Empirical results

This section starts by discussing the relative size of tax-benefit instruments in Ecuador and Colombia and providing a basic portrait of labour formality in the two countries. We then present results of predicted earnings for informal workers in the formal sector. Finally, we provide a detailed analysis of formalization tax rates in both countries and discuss the implications of formalization in terms of distributional and budgetary effects.

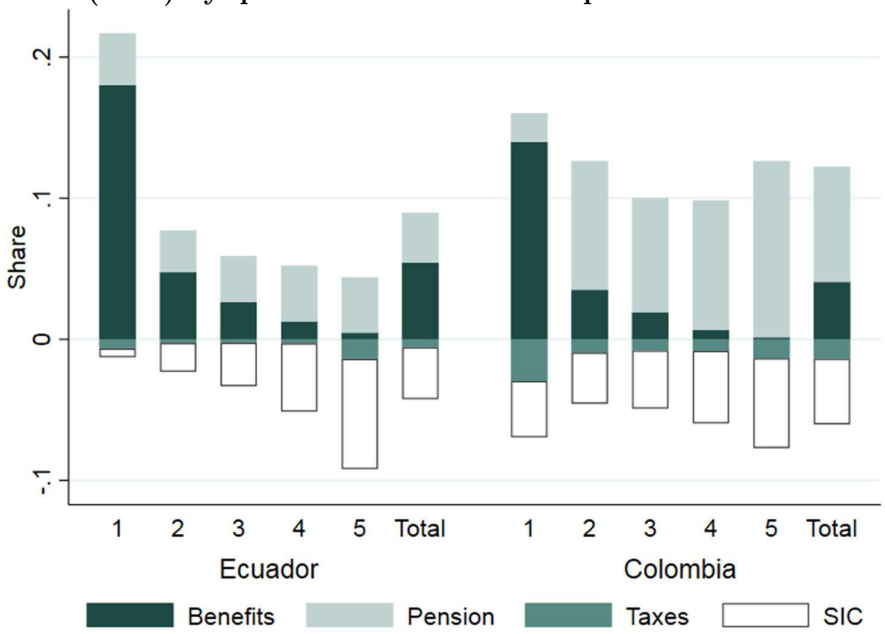
1.4.1 Tax-benefit instruments in Ecuador and Colombia

Figure 1.1 shows the main results of the microsimulations models for the two countries. For each income quintile it presents the contribution of each policy instrument to disposable income. Several features of the systems are worth noting. Benefits are progressive in both countries and represent a larger share of disposable income in Ecuador than in Colombia. They represent around 18 percent of disposable income in the bottom quintile in Ecuador, whereas they account for 14 percent of the same group in Colombia. Pensions play a larger role in Colombia, however, their relative size increases along the income distribution, representing a larger share of disposable income for richer households.

Personal income tax plays, on the other hand, only a minor role due to the presence of high non-taxable thresholds and deductions from personal expenditures in the two countries; it represents less than 3 percent of disposable income regardless of the quintile. However, property and car taxes are burdensome, especially for the first quintile in Colombia. Finally, SICs are more progressive in Ecuador than in Colombia. For the first quintile the share is almost 4 percent in Colombia but less than 1 percent in Ecuador. This might be related to the fact that Colombian self-employed workers

below the minimum wage are required to contribute on the basis of the minimum wage if they are affiliated to social security, but contribution is voluntary in Ecuador. It could also be associated with the presence of *Seguro Campesino* in Ecuador, a rural worker social insurance regime for self-employed rural workers with lower contribution rates than the general regime. [11]

Figure 1.1. Mean share of tax-benefit instruments in household disposable income (2014) by quintiles of household disposable income



Source: Authors' own calculations based on the microsimulation models.

Results from our tax-benefit simulations also highlight the reduced effect of government intervention on income inequality. In line with previous research we found that the redistributive effect of the tax-benefit system in Colombia is very small (the Gini coefficient from market income equals 0.587 compared to 0.561 based on disposable income), whereas the Ecuadorian tax-benefit system has a greater impact in reducing inequality (with a reduction in the Gini coefficient from 0.501 to 0.464 when market income is compared to disposable income).[12] Alternatively, the P80/P20 ratio of disposable income is remarkably higher for Colombia than for Ecuador, amounting to 21.4

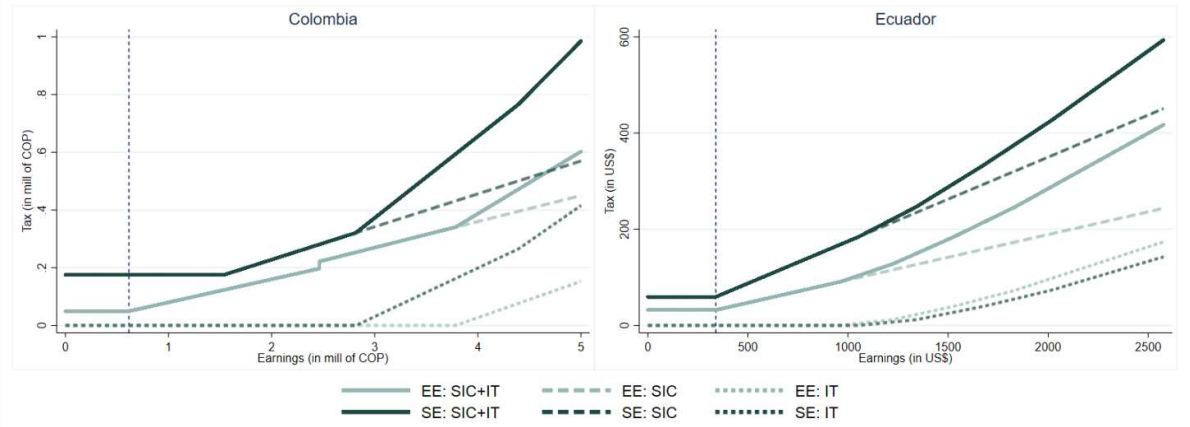
[11] The amount of SICs paid by members of the rural worker social security regime is equal to 2.5 per cent of 22.5 per cent of the minimum wage.

[12] As a point of comparison, for the 28 European countries in EUROMOD, government intervention reduced the Gini coefficient 21 percentage points from 0.505 (market income) to 0.296 (disposable income).

compared to 10.5, respectively. When applying this measure to market income, results are 26.4 and 14, respectively.[13]

To further analyse the effect of the tax-benefit system on informality, Figure 1.2 presents income tax and social contributions as a function of gross earnings for hypothetical workers. We assume for simplicity that other sources of income and income tax deductions are zero. From the figure it is important to highlight the fixed payment in social insurance contributions required in case formal earnings are between zero and the monthly minimum wage in both countries. Considering that most informal workers are on this earnings interval, the fixed payment will play an important negative role in our measure of incentives to formalize. On the other hand, income tax is not as high (relative to earnings) as social contributions and it affects only those workers earning at least three monthly minimum wages, therefore, its role will be minor in terms of formalization incentives.

Figure 1.2 Formal worker's tax, social contributions, and gross earnings (2014)



Source: Authors' own calculations based on the microsimulation models. Note: SIC: Social Insurance Contributions, IT: Income Tax. All other sources of income different than earnings and deductibles were set to zero. The monthly minimum wage is shown by the vertical dotted line.

1.4.2 A portrait of informal employment in Ecuador and Colombia

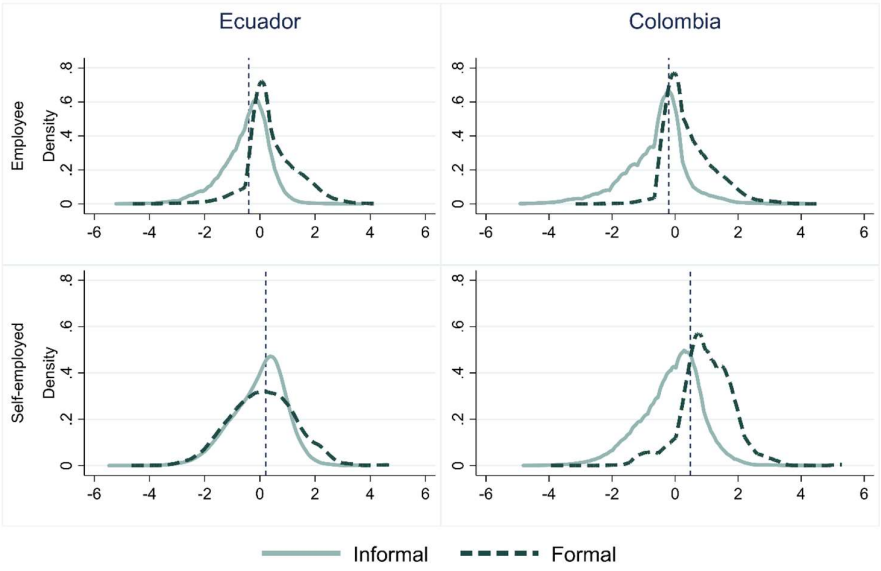
Our two countries are characterised by very high levels of informality. The unconditional labour informality rate at the population level reaches 58 percent in Ecuador and around 65 percent in Colombia. Moreover, there are also marked differences in the structure of the informal economy (see Table A1 in the Appendix). In Colombia, the majority of informal workers are self-employed (67 percent), whereas the composition is more balanced in Ecuador with around 47 percent of self-

[13] Lustig (2017) assesses the effect of taxes and benefits in Latin America finding similar results for the reduced role of government for several countries including Ecuador and Colombia.

employed workers in the informal sector. In both countries, the largest share of informal workers comprises low-skilled workers with low earnings (bottom two quintiles).

Figure 1.3 presents the distribution of labour income by formality status. The vertical dotted line represents the national minimum wage. In most cases there is a natural partition of informal (solid distribution) and formal earnings (dashed distribution) below and above the minimum wage respectively, which is consistent with the exclusion perspective.[14] There is only one exception to this pattern. For self-employment income in Ecuador, both distributions (formal vs informal) are very similar and symmetric around the minimum wage, which is consistent with the exit perspective and possibly as a result of SICs not being mandatory for the self-employed in Ecuador.

Figure 1.3 Earnings distribution of formal and informal workers (2014)



Source: Authors' own calculations based on household surveys. Note: the minimum wage is shown by the vertical dotted line.

Table 1.1 presents probit estimates of the main determinants of labour formality. We include as dependent variables those previously used in the literature such as age, gender, dummies for education, rural area, industry and occupation, and variables related to the household, namely a dummy for living with a couple and the number of children. Our results for most variables are in line with the previous literature. For instance, Carneiro and Henley (2002) for Brazil; Uribe et al., (2007) for Colombia; Delgado y Navarro (2013) for Costa Rica or Cuevas et al., (2016) for Mexico.

[14] It is important to highlight that the unconditional labour income (regardless of formality status) of almost half of workers in both countries is below the minimum wage.

The models confirm the concave effect of age and the remarkable increase in the likelihood of being a formal sector worker with additional schooling. In Colombia rural workers are less prone to working in the formal sector, whereas in Ecuador the opposite is observed due to the presence of the abovementioned *Seguro Campesino*. Finally, living as a couple increases the chance of being in the informal sector, and the probability of being in the formal sector decreases with the number of children in the household.

Table 1.1 Determinants of Labour Formality: AME of probit estimates

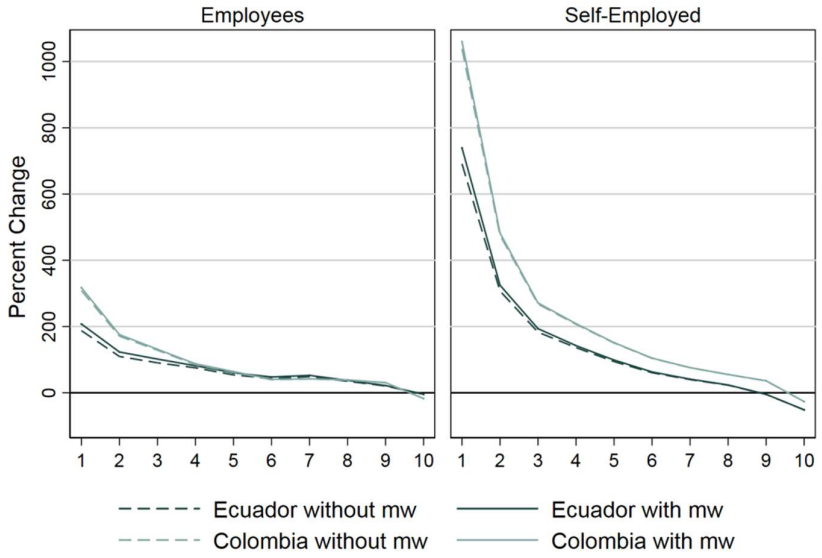
	Ecuador	Colombia
Male	0.065***	0.085***
	(16.09)	(17.28)
Age	0.012***	0.022***
	(14.88)	(20.48)
Age sq.	-0.00011***	-0.00028***
	(-12.08)	(-21.16)
Secondary education	0.150***	0.150***
	(33.08)	(25.73)
Tertiary education	0.381***	0.344***
	(75.72)	(51.85)
Couple	0.069***	0.038***
	(15.76)	(7.36)
Number of children	-0.015***	-0.013***
	(-8.16)	(-5.29)
Rural	0.058***	-0.032***
	(11.33)	(-5.53)
Industry dummies	Yes	Yes
Region dummies	Yes	Yes
Pseudo R^2	0.153	0.267
# Observations	56,340	27,786
# Informal Workers	32,776	20,100

Source: Authors' own calculations based on household surveys Notes: delta-method t statistics in parentheses, significance level: *** p<0.01

1.4.3 Earnings differentials between sectors

This section briefly discusses the results of our predictions of earnings for informal workers in the event of entering formality, based on the estimation of Equation 1. Figure 1.4 summarizes the results, presenting the percentage change in earnings by earnings deciles of informal workers before the transition. The table distinguishes between employees and the self-employed due to the marked differences in the change in earnings obtained from the predictions. Results from the earnings estimation are presented in Table A1.2 in the Appendix.

Figure 1.4 Percentage change in labour income by decile of baseline earnings of each type of informal work



Source: Authors' own calculations based on household surveys.

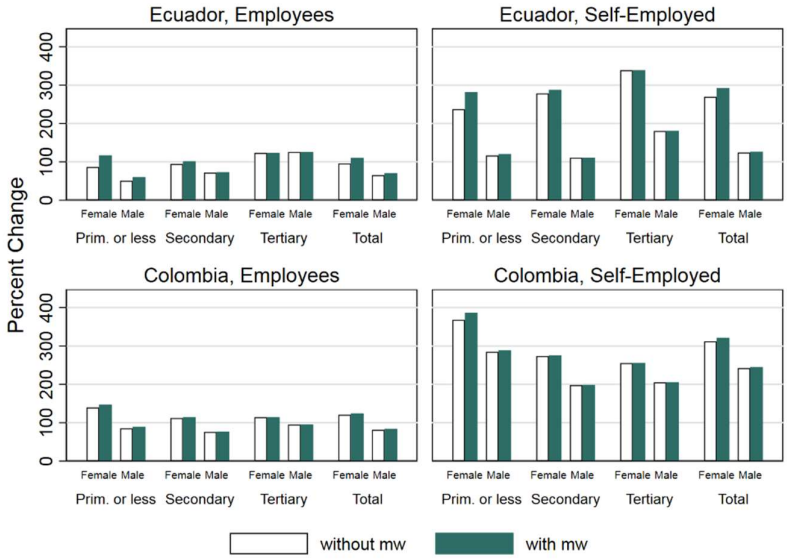
As depicted in Figure 1.4, changes in earnings resulting from the econometric estimates are positive for most informal workers except for those in the last decile of baseline earnings.[15] Gains are on average larger for workers in Colombia (210 percent) than in Ecuador (132 percent), for the self-employed (230 percent) compared to employees (80 percent), and for rural workers (203 percent) compared to urban workers (142 percent). Most predicted formal earnings for informal workers are already above the minimum wage; therefore, the lines with and without the minimum wage are frequently on top of each other in Figure 1.4, with the average gains increasing only slightly when minimum wage enforcement is imposed. These increases do not imply that earnings gaps between women and men or between rural and urban workers disappear. As a matter of fact, these formal earnings gaps remain for previously informal workers.

Figure 1.5 presents the percentage change in labour income after formalization for different groups of informal workers. Earnings gains are higher for women than men in the informal employment, with the minor exception of employees with tertiary education in Ecuador. In this country, the higher the education level achieved the larger the formalization gains; in Colombia the opposite

[15] Around 25 percent of the sample in Ecuador and 17 percent in Colombia would experience a decrease in earnings according to our predictions.

holds. Moreover, when we consider the enforcement of the national minimum wage there is a small additional increase in earnings gains for workers with primary or no education, especially for Ecuador. Nevertheless, even from this perspective we observe that counterfactual earnings are mostly above the minimum wage for most groups of informal workers. Therefore, for simplicity, throughout the rest of the paper we use the counterfactual incomes, which include the adjustment for minimum wage enforcement.

Figure 1.5 Percentage change in labour income by groups of gender, education and worker type

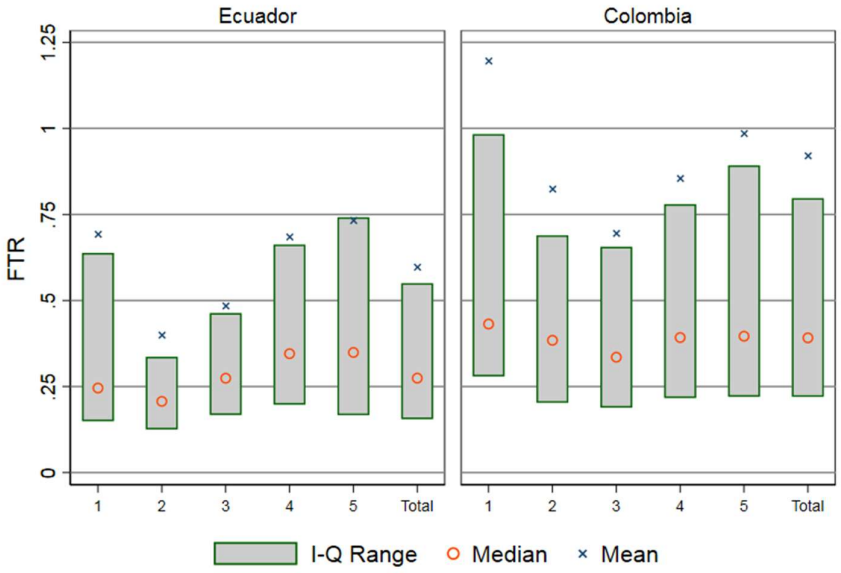


Source: Authors' own calculations based on household surveys. Note: mw, minimum wage.

1.4.4 Financial disincentives to formal employment

This section focuses on the analysis of our FTR indicator (equation 3) measuring the proportion of the change in earnings that would be taxed away in the form of increased SICs and taxes or reduced benefits following a transition from the informal to the formal sector. We start with an analysis of the distribution of FTRs in Ecuador and Colombia, distinguishing between employees and self-employed informal workers who show contrasting patterns in both countries. We then discuss the contribution of different tax-benefit components to FTRs. Finally, we compare how formalization costs vary across different population subgroups.

Figure 1.6 FTR by quintile of baseline earnings in informality



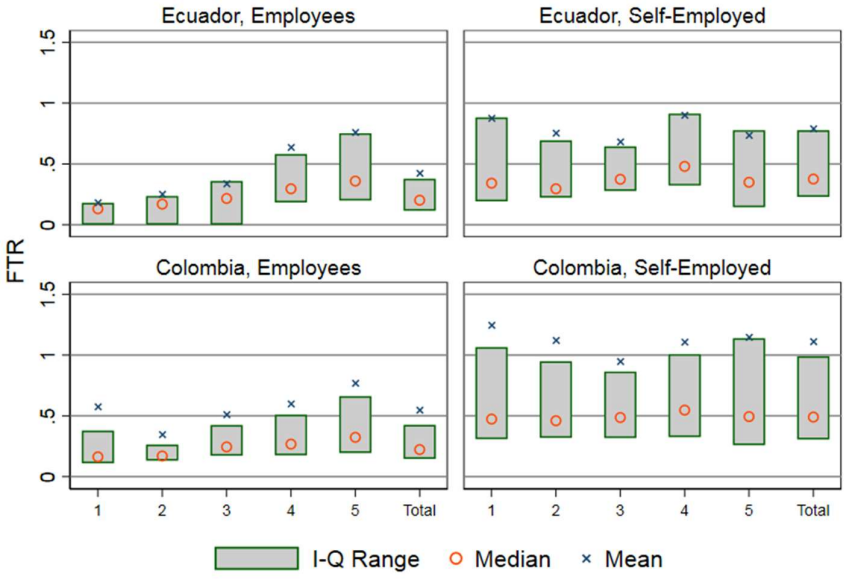
Source: Authors' own calculations based on microsimulation models

Distribution of FTRs. Figure 1.6 presents mean and median FTRs, as well as percentiles 25 and 75 of FTR per quintiles of earnings in informality. Our results point to the presence of high FTRs in the two countries, but particularly so in Colombia. Mean FTRs equal 60 percent in Ecuador and 92 percent in Colombia, meaning that in Colombia (Ecuador) 92 (60) percent of the change in earnings gained from formalization would be taxed away as a result of increased SICs and tax payments or reduced benefits. In both countries, a U-shaped relationship between FTRs and earnings is observed. Mean FTRs are particularly high for workers in the bottom quintile of the earnings distribution, with mean FTRs of 69 percent in Ecuador and 120 percent in Colombia for this group. In Ecuador, workers in the top earning quintile face the highest FTRs of around 73 percent, whereas for Colombia mean FTRs for this group are slightly below 100 percent. The information of median FTR and percentiles 25 and 75 of FTR depict that FTRs are skewed to the right, with means systematically above the 75 percentile.

Figure 1.7 presents similar results, but now distinguishing between informal employees and informal self-employed workers. The results show very different patterns across these population groups. In Ecuador, FTRs increase with earnings of informal employees, whereas the pattern is less clear for the self-employed with a U-shaped pattern up to the fourth quintile of the distribution but a fall in FTRs for the top quintile. In Colombia, for both employees and self-employed informal workers

we observe a somewhat U-shaped pattern between mean FTRs and informal earnings. However, the pattern of mean FTRs seems to be driven by observations with high values of FTRs. In fact, median FTRs increase with earnings in the case of informal employees and are relatively constant for the self-employed. Looking at Figures 1.6 and 1.7, it becomes evident that the pattern of mean FTRs for the whole informal population is mainly driven by the pattern of mean FTRs of the self-employed.

Figure 1.7 FTR by category of employment by quintile of informal earnings of each category



Source: Authors' own calculations based on microsimulation models

Formalization costs are mostly driven by the design of SICs in each country.[16] In Colombia, a minimum contribution based on the national minimum wage applies to both employees and the self-employed, even if their labour income is below the minimum wage. The same applies to full-time employees and the self-employed in Ecuador, whereas part-time employees contribute on the basis of the proportion of the minimum wage based on their working days.[17] These features of the SICs system pose an extremely high burden on formalization, particularly for low earners who

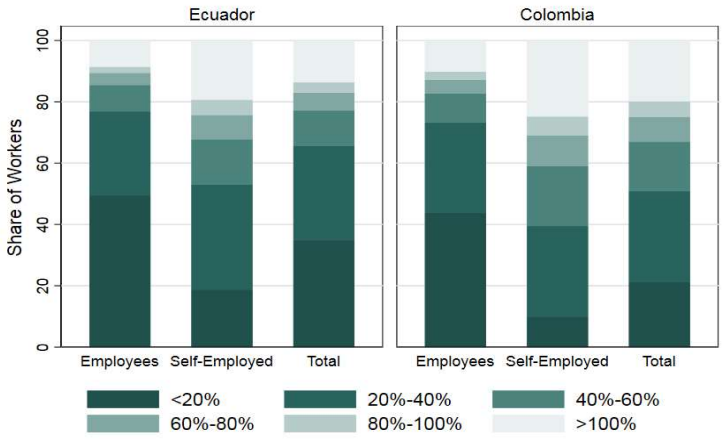
[16] As depicted in Figures 1.1 and 1.2, income taxes are not particularly binding and there are no activation clauses that prevent formalizing workers receiving means tested benefits; therefore, the effect is driven almost completely by SICa.
[17] For self-employed workers, these minimum contributions are equal to 20.5 and 28.5 percent of the minimum wage for Ecuador and Colombia respectively. For employees they are 9.45 and 8 percent respectively.

represent the largest proportion of informal workers in the two countries. The higher FTRs for the self-employed are the result of lower earnings among this group of informal workers.

An in-depth analysis of the distribution of FTRs is presented in Figure 1.8, which shows the share of workers at different ranges of FTRs. In Ecuador, around 65 percent of informal workers face an FTR below 40 percent whereas in Colombia this group is smaller, representing around 50 percent of the informal population. On the other hand, the percentage of workers facing high disincentives to formalization, that is FTRs above 100 percent, is much higher in Colombia, representing 20 percent of informal workers, against 15 percent in Ecuador.

Figure 1.8 Share of workers by range of FTR (2014)

Employees and self-employed



Source: Authors' own calculations based on microsimulation models

The higher concentration of FTR in the upper part of the distribution for Colombia could be explained by the relative share of employees and self-employed in informal work. As we pointed out before, self-employed informal workers are predominant in Colombia whereas the divide between employees and self-employed workers is more balanced in Ecuador. Additionally, self-employed workers face higher SIC rates than employees in both countries. Therefore, the penalty must be larger in Colombia and it is important to analyse formalization incentives separately for these two groups.

Decomposition of FTRs. As previously mentioned, the distribution of FTRs and their differences across groups are most likely related to the design of SICs in the two countries. A

decomposition of our FTRs measures following equation 4 confirms that SICs are the instrument contributing the most to the financial cost of formalization.

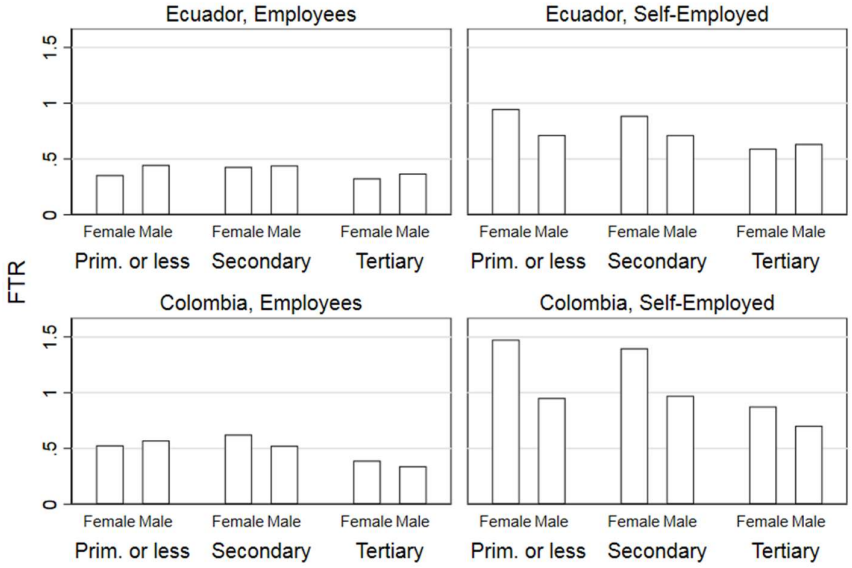
The contribution of cash transfers to FTRs is practically null because in both countries, eligibility to benefits (that is, conditional cash transfers) does not depend directly on the formal status of the person but on composite welfare indexes (being below a certain threshold of the index), with the minor exception of the elderly and the disabled in Ecuador who are not part of the sample of analysis. The effect of taxes is minimal, with a marginal contribution noticeable only for the top decile of the earnings distribution. In Ecuador, taxes contribute 1.5 percentage points of FTR in the top decile, whereas their contribution for this group represents 0.16 percentage points in Colombia. The minor effect of taxes is due to the two characteristics of personal income tax mentioned before. First, in both countries the non-taxable threshold is very high, meaning that most informal workers would not enter the tax brackets to be liable for income tax on entry to formality. Second, even if after transition to formal employment, the earnings gain of informal workers results in taxable income above the non-taxable threshold, deductions from personal expenditures can be made from taxable income, meaning that effectively very few workers would be subject to income tax payments. Nevertheless, we do observe a higher contribution of taxes to formalization costs in Ecuador than in Colombia, resulting from the higher progressivity of income tax in the first country, as discussed in Section 1.4.1.

Heterogeneity across population subgroups. The results from the previous section have already highlighted the importance of looking at FTRs across different population subgroups. We observed important differences in formalization costs between employees and the self-employed. However, there could be other patterns for different groups of the population. Figure 1.9 compares mean FTRs by gender, education, and type of work status, that is, employment vs self-employment.

Our results provide a number of interesting findings. First, as previously acknowledged, the largest differences in FTRs are observed between employees and self-employed informal workers. Second, informal workers with tertiary education face on average lower disincentives to formalization independent of their gender, with differences more pronounced for self-employed workers particularly in Colombia. Third, differences in formalization costs between male and female employees are small, but they are large between male and female self-employed workers. Female self-employed workers

without tertiary education face particularly high FTRs compared to their male counterparts. The gap in FTRs between these two groups is around 42 percentage points in Colombia, and 23 percentage points in Ecuador.

Figure 1.9 Mean FTRs by gender, education, and type of work (2014)

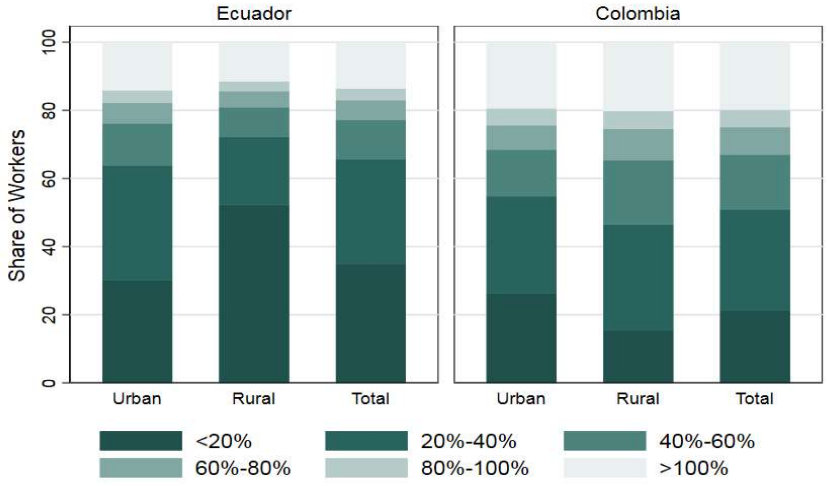


Source: Authors' own calculations based on microsimulation models. Note: mean of each component

Another interesting divide to consider in the analysis of FTRs is the one between workers in rural and urban areas. Our results show that there are important differences in FTRs between workers in rural and urban areas in Ecuador, but less so in Colombia. In Ecuador, mean FTRs for rural workers are 48 percent and for urban workers are 63 percent on average, whereas in Colombia they represent 95 and 89 percent for rural and urban workers, respectively. The distribution of FTRs for rural and urban workers in the two countries is depicted in Figure 1.10, which presents the share of workers at different ranges of FTR. The figure for Ecuador shows that the percentage of informal workers facing low FTRs (FTRs below 20 percent) is much higher in rural areas than urban areas (50 percent compared to 30 percent of workers). The opposite is observed in Colombia. The rural urban pattern observed in Ecuador is related to the presence of *Seguro Campesino* in this country.

Figure 1.10 Share of workers by range of FTR (2014)

Rural-Urban classification



Source: Authors' own calculations based on microsimulation models

To better capture the patterns of FTRs across different population subgroups, Table 1.2 presents mean and median regression estimates of FTRs on a range of personal characteristics. As expected, the beta coefficients of the mean regression are higher in absolute terms than those for the median regressions. However, the direction of the effect in both estimations is in most cases the same. Our regression results confirm that male workers have lower FTR (mean and median) than female workers. The differences in formalization costs between women and men are the result of differences in earnings. Informal earnings of female workers are so low that despite a higher increase in (counterfactual) earnings on entry to formal employment compared to male workers, a relatively fixed payment of SICs is more burdensome.[18] Controlling for other characteristics we observe that FTRs decrease with both age and education.

We find no clear pattern of FTRs depending on the quintiles of informal earnings, when mean and median regressions are compared. From the mean regressions a U-shaped relationship emerges but, alternatively, from the median regressions the higher the informal earnings the higher the formalization costs. Note that this finding is consistent with the results presented in Figures 1.5 and 1.6.

[18] Social contributions are relatively constant due to the above-mentioned fixed contribution based on the minimum wage.

Table 1.2 Mean and Median regression estimates of FTR

	Ecuador		Colombia	
	mean	median	mean	median
Male	-0.126***	-0.053***	-0.374***	-0.100***
	(-8.79)	(-11.55)	(-12.2)	(-12.93)
Secondary	-0.081***	-0.018***	-0.089***	-0.061***
	(-5.64)	(-4.01)	(-2.76)	(-7.53)
Tertiary	-0.246***	-0.071***	-0.473***	-0.204***
	(-11.54)	(-10.49)	(-8.03)	(-13.78)
Age (25-34)	-0.090***	-0.037***	-0.121***	-0.053***
	(-4.67)	(-6.01)	(-2.68)	(-4.65)
Age (35-44)	-0.166***	-0.074***	-0.170***	-0.085***
	(-8.08)	(-11.35)	(-3.65)	(-7.22)
Age (45-54)	-0.213***	-0.084***	-0.222***	-0.097***
	(-9.58)	(-11.86)	(-4.67)	(-8.09)
Age (55-)	-0.244***	-0.092***	-0.281***	-0.097***
	(-8.54)	(-10.1)	(-4.89)	(-6.74)
Self-Employed	0.366***	0.183***	0.607***	0.289***
	(25.48)	(40.19)	(19.64)	(37.22)
Rural	-0.082***	-0.096***	0.095***	0.070***
	(-5.11)	(-18.94)	(3.08)	(9.08)
Quintile 2	-0.164***	0.003	-0.217***	0.013
	(-8.02)	(0.47)	(-5.15)	(1.22)
Quintile 3	-0.043**	0.082***	-0.220***	0.064***
	(-2.08)	(12.54)	(-4.61)	(5.31)
Quintile 4	0.165***	0.155***	0.022	0.148***
	(7.59)	(22.52)	(0.46)	(12.59)
Quintile 5	0.149***	0.137***	0.197***	0.195***
	(6.84)	(19.87)	(4.00)	(15.76)
Constant	0.695***	0.251***	0.981***	0.280***
	(28.73)	(32.63)	(16.67)	(18.91)
Observations	28147	28147	16386	16386
Adjusted or pseudo R^2	0.0464	0.0494	0.0389	0.0476

Source: Authors' own calculations based on microsimulation models Notes: t statistics in parenthesis, significance level: * p<0.1, ** p<0.05, *** p<0.01

Table 1.2 confirms that FTRs are higher for the self-employed compared to employees. The higher formalization costs for this group of workers are explained entirely by the tax and benefit system. In fact, counterfactual (predicted) earnings in formal employment for self-employed informal workers are higher than those for employees. However, higher social contribution rates for these groups and the abovementioned minimum contribution translates into a higher cost of formalization. Finally, rural workers have lower mean and median FTRs than urban workers in Ecuador, but the opposite is observed for workers in Colombia. As previously mentioned, this is due to the presence of the rural worker social insurance regime (*Seguro Campesino*) in Ecuador.

Alternative measures of Formalization costs. In the appendix we present two sets of additional figures on the formalization burden based on Koettl and Weber's (2012) original definition of formalization tax rates. It is however important to re-emphasise here that this measure is not comparable with ours, as their formula measures the change in disposable income on entry to formal employment as a percentage of earnings in informality, rather than as a percentage of the change in earnings following formalization.

In the first set of results we compute formalization costs following Equation 2 above (see Figures A1.1 A1.2). Using Koettl and Weber's (2012) definition we find much higher FTRs for low earning self-employed workers relative to FTRs with our definition. This is because the burden of SIC relative to current self-employed earnings is high whereas the change in earnings after formalization is high enough to make our indicator relatively lower. Notice also that relative to original earnings our definition of FTR is U-shaped while Koettl and Weber's (2012) definition is decreasing. This is the case because at the top of the distribution there is a reduced (even negative) change in earnings making the denominator smaller than the tax burden.

The appendix also presents results of an alternative exercise in which we compute the burden that formal workers face being in their sector instead of the informal sector (see Figures A1.3 and A1.4). For simplicity, we assume no earnings change and use a modified version of Equation 2 that we present in the appendix. FTRs for formal workers are consistently lower than for informal workers. This is because baseline earnings (the denominator) are higher in the formal sector. FTRs for formal workers are mostly clustered on the interval 0 to 30 percent implying that the burden of being in the formal sector is not high relative to formal earnings. This is especially true if we consider that the benefits associated to SIC are valued by workers.

1.4.5 Distributional implications of formalization

An important advantage of tax-benefit microsimulation is that it allows us to study the distributional implications of counterfactual scenarios. In this section, we consider a counterfactual situation in which all informal workers would be formalized. Note that this exercise is slightly different from the approach used to simulate transitions into formal employment in the previous sections. The previous analysis was aimed at calculating the formalization cost of each informal worker in the event of entering formal employment. For this, we simulated transitions into unemployment

separately for each informal worker in the household, in the case that there was more than one informal worker. In this section, our counterfactual assumes that all informal workers would be formalized at the same time, meaning that for households with more than one informal worker, we would calculate household disposable income when all of them are formal. Notice also that this exercise by construction omits the general equilibrium effects on earnings that such a tough experiment will necessarily imply. However, it gives us an important picture of the burden that labour informality creates on poverty, inequality and, as will be shown in the next section, government finances.

Table 1.3 Distributional measures for the formalization exercise

	Ecuador				Colombia			
	Baseline	Earnings change without transition	Transition without earnings change	Transition with earnings change	Baseline	Earnings change without transition	Transition without earnings change	Transition with earnings change
Gini coefficient								
Market income	0.501	0.466	0.501	0.466	0.587	0.519	0.587	0.519
Disposable income	0.464	0.432	0.472	0.438	0.563	0.498	0.606	0.524
P80/P20 ratio								
Market income	13.95	12.07	13.95	12.07	26.39	17.71	26.39	17.71
Disposable income	10.52	9.35	10.98	9.55	21.47	13.95	46.06	17.32
Poverty headcount								
Market income	0.197	0.148	0.197	0.148	0.431	0.28	0.431	0.28
Disposable income	0.16	0.119	0.187	0.133	0.397	0.248	0.464	0.309

Source: Authors' own calculations based on microsimulation models.

Table 1.3 presents some distributional effects of the counterfactual exercise. In particular, four different scenarios are evaluated in order to differentiate two different effects when we consider formalization of workers in the informal sector. The first scenario (baseline) presents inequality and poverty indicators for the economy as it is, without assuming any change in individuals' circumstances. The second scenario (earnings change without transition) considers a counterfactual distribution in which informal workers would face similar earnings as their formal counterparts but would still pay no SICs and no taxes. The third scenario (transition without earnings change) represents a situation in which informal workers would start contributing to SICs and paying taxes but under the same earnings they currently have in the informal sector. Finally, the last scenario (transition with earnings change) considers our main counterfactual scenario, in which informal

workers would enter formal employment (pay SICs and taxes) but receiving counterfactual earnings based on those observed for formal workers.

A comparison of the baseline results with our main counterfactual scenario (transition with earnings change) shows that market income inequality, measured by the Gini coefficient, would be reduced by 3.5 and 6.8 percentage points in Ecuador and Colombia, respectively. The effect on market income inequality is driven by the increase in earnings of informal workers on entry to formality, because most informal workers are at the bottom of the distribution. In the case of disposable income inequality, the Gini coefficient would decrease in both countries but less than the decrease observed in market income inequality. Around three-quarters and three-fifths of the reduction in market income inequality would not translate into a reduction of disposable income inequality in Ecuador and Colombia respectively, because they are offset by high social contributions for workers who enter formality.

Our intermediate counterfactual scenarios allow us to disentangle the two combined effects affecting disposable income inequality. Under our scenario in which earnings of informal workers would match those of formal workers but without entry to formal employment (i.e. without liability to SICs or taxes), the decrease in market income inequality translates almost one to one in a reduction of disposable income inequality. On the other hand, under the scenario of a transition to formal employment without earnings change, we would observe an increase in the Gini coefficient from disposable income of around 1 percentage point in Ecuador and 4.3 points in Colombia.

Another way to look at this increase in inequality is by means of the ratio of disposable incomes for the top 20 percent and bottom 20 percent of the population. This indicator increases by around 4 percent for Ecuador but more than doubles for Colombia, that is, enforcing social insurance payments affects the poor in Colombia disproportionally more.

Finally, under our main counterfactual scenario, assuming informal workers would enter formal employment (i.e. pay SICs and taxes) with earnings similar to those of workers in the formal sector, income poverty would decrease by 3 and 9 percentage points in Ecuador and Colombia respectively.[19] This positive effect is fully driven by the (counterfactual) earnings gains of informal

[19] For poverty measures we apply national poverty lines calculated by the statistics office of each country. In the case of Colombia, we apply different lines for rural and urban areas.

workers. In fact, assuming that informal workers would experience the same change in earnings but without contributing to social security or paying taxes, an additional decrease in poverty of around 1 and 6 percentage points would be observed in Ecuador and Colombia respectively. On the contrary, if informal workers become liable to pay SICs and taxes but under the same earnings they receive in informal employment, poverty would increase by 3 and 7 percentage points relative to the baseline in Ecuador and Colombia, respectively.

1.4.6 Budgetary implications of formalization

In this section we present the budgetary effects of the main counterfactual scenario of Section 1.4.5, in which all informal workers would enter formal employment (i.e. pay SICs and taxes) and have change in earnings based on the labour income of workers in the formal sector. Table 4 presents aggregate revenue from SICs and taxes in our baseline and reform scenario. In the case of SICs, we differentiate between workers' and employers' SICs to analyse who would bear a higher burden from formalization. Table 1.4 also compares changes in aggregate earnings, market income, and disposable income in our baseline and reform scenarios.

Table 1.4 Budgetary Effects of different scenarios (2014)

	Ecuador			Colombia		
	Baseline	Reform	Change	Baseline	Reform	Change
	USD (Millions) per year		(%)	COP (Billions) per year		(%)
Worker's SIC	2,721	4,767	75.2%	14.77	33.74	128.4%
Employer's SIC	1,826	2,991	63.8%	28.77	40.71	41.5%
Total SIC	4,547	7,758	70.6%	43.53	74.45	71.0%
Income Tax	724	766	5.8%	3.37	3.42	1.3%
Earnings	39,245	43,221	10.1%	235.67	268.94	14.1%
Market Income	46,715	50,691	8.5%	258.14	291.4	12.9%
Disposable Income	45,597	47,486	4.1%	268.51	282.77	5.3%

Source: Authors' own calculations based on microsimulation models.

Given the high levels of informality in Ecuador and Colombia, aggregate revenue from SICs would increase considerably under our counterfactual scenario. In both countries, revenue from SICs would increase by around 71 percent. Moreover, because of the large proportion of self-employed workers in the informal sector and due to the higher contribution rates for this group of workers, the burden from formalization would be larger for workers than for employers. As shown in the table, aggregate revenue from workers' SICs would increase by nearly 75 percent in Ecuador and 128 percent in

Colombia. Aggregate revenue from employers' SICs would, on the other hand, rise by 64 and 42 percent in Ecuador and Colombia, respectively.

On the contrary, the increase in tax revenue would be modest due to the high non-taxable thresholds and deductions from personal expenditures characterising the design of personal income tax in the two countries. Income tax revenue would increase by 5.8 percent in Ecuador and only 1.3 percent in Colombia. Finally, formalization of informal workers under our counterfactual scenario would represent an increase in aggregate earnings of 10 and 14 percent in Ecuador and Colombia respectively. The increase in aggregate market income would fully reflect the increase in aggregate earnings, whereas the increase in aggregate disposable income would capture both, the effect of increased earnings but also the increase in SIC and tax payments.

1.5 Conclusion

Despite recent efforts to encourage formalization by governments in Latin America, a large share of the working force in the region still work in the informal sector. Understanding the role of the tax-benefit system in creating disincentives to enter formal employment is paramount when considering potential policies aiming at reducing the prevalence of the informal sector in the economy. Focusing on the worker's perspective, this paper aimed to quantify the costs that informal workers would incur in the event of entering formality, due to social insurance and tax payments, as well as the potential loss of cash benefits.

In order to measure the cost of formalization, the approach proposed in this paper is to exploit the advantages offered by tax-benefit microsimulation models and simulate transitions from informal to formal employment for all workers observed in informal jobs in nationally representative household survey data from Ecuador and Colombia. Microsimulation models provide a comprehensive way to assess the effect of different tax-benefit instruments on individuals' financial (dis)incentives to enter formality. Moreover, in contrast with previous research, we account for the fact that informal workers would not necessarily face the same earnings upon entering formal employment and this would influence their financial incentives to formalization.

Our results show that despite potential gains in earnings on entry to formality, formalization costs are strikingly high in both countries, mainly due to the design of SICs. In the two countries, most

informal workers are at the bottom of the earnings distribution and despite a large gain in earnings on entry to formality, the existence of minimum SIC payments represents a significant financial burden. On average, around 60 and 92 percent of workers' change in earnings in a formal job would be taxed away in the form of increased taxes and SICs in Ecuador and Colombia, respectively. Moreover, formalization costs vary widely across different population subgroups with the most marked differences found between employees and self-employed informal workers. Finally, under a counterfactual scenario in which all informal workers would be formalized income inequality would decrease due to a potential improvement in earnings of (previously) informal workers; the burden posed by the tax-benefit system is however very important. This is especially true in Colombia, where a 6.8 percentage points decrease in market income inequality would translate into a lower, 4 percentage points, decrease in disposable income inequality.

From a policy perspective, our analysis highlights that government strategies aiming to increase formalization necessarily need to review the design of tax-benefit systems. In Ecuador and Colombia, minimum payments of SICs would represent an important burden to self-employed informal workers with low earnings in the event of formalization. The Ecuadorian system represents an example of how to account for the specificities of the labour market in the design of SICs. A specific social insurance regime *(Seguro Campesino*) exists in Ecuador to cover self-employed rural workers, with lower contribution rates than those in the general regime. Similar designs could be considered to target other categories of self-employed workers characterised by low earnings in the two countries.

Due to the challenging nature of labour market informality, some caveats are worth noting. First, our analysis focuses on the financial disincentives to formal employment embedded in the tax-benefit system. The choice between the formal and informal sectors are, however, also associated with other factors. As stressed by the exclusion perspective, there could be barriers between formal and informal activities, and these might vary depending on worker characteristics. Accounting for these potential demand-side constraints is important for highlighting the nature of informality not only as a choice but also as a lack of opportunities. Second, our analysis has been purely static in the sense that payments of SICs are considered a cost in the short-term. However, from a dynamic perspective, workers might value benefits derived from SICs. In both countries, SICs entitle the

worker to sickness, paternity, and maternity leave, and in the long-run to a pension. As such, our measure of FTR might overestimate the cost of formalization. Third, our distributional and budgetary analysis of the counterfactual fully formalized economy was purely illustrative and did not account for second or higher-order effects of the proposed formalization. As depicted by the large budgetary effects of such scenarios, general equilibrium effects should be considered to provide a broader picture of such changes. All these extensions represent promising areas for future research.

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A.1 Appendix

Table A1.1 Descriptive statistics for Ecuador and Colombia

	Colombia			Ecuador		
	Formal	Informal	All	Formal	Informal	All
Sample of Observations	7,686	20,100	27,786	23,564	32,776	56,340
Total Population (in thousands)	6,771	12,635	19,406	2,352	3,196	5,548
Share of Employees	0.86	0.33	0.51	0.88	0.56	0.69
Share of Self-Employed	0.14	0.67	0.49	0.16	0.47	0.34
Share of Skilled	0.42	0.09	0.21	0.36	0.11	0.22
Share of Unskilled	0.58	0.91	0.79	0.64	0.89	0.78
Share of Rural	0.07	0.28	0.21	0.22	0.28	0.25
Share of Urban	0.93	0.72	0.79	0.78	0.72	0.75
Share of Female	0.40	0.38	0.39	0.39	0.38	0.38
Share of Male	0.60	0.62	0.61	0.61	0.62	0.62
Share of Ethnic minorities	0.10	0.17	0.15	0.11	0.17	0.14
Share of Part-Time	0.50	0.76	0.67	0.54	0.79	0.68
Share of 1st quintile	0.01	0.30	0.20	0.08	0.30	0.21
Share of 2nd quintile	0.03	0.30	0.21	0.09	0.28	0.20
Share of 3rd quintile	0.25	0.16	0.19	0.29	0.15	0.21
Share of 4th quintile	0.31	0.14	0.20	0.21	0.17	0.18
Share of 5th quintile	0.40	0.09	0.20	0.33	0.10	0.20
Average monthly earnings LCU	1,464,720	569,009	881,522	716	346	503

Source: Authors' own calculations based on household surveys

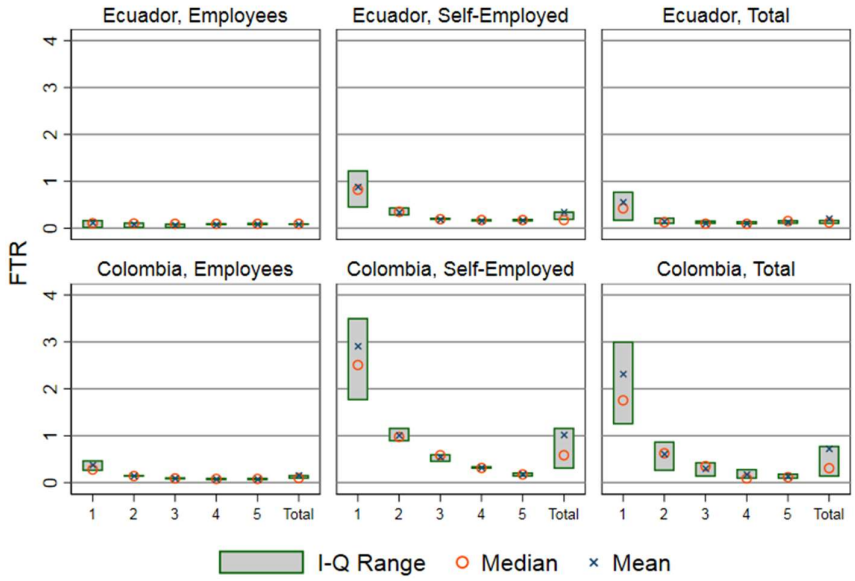
Table A1.2. OLS estimates of log hourly wages for formal workers

	Ecuador	Colombia
Age (25-29)	0.10418***	0.10225***
	(6.36)	(3.79)
Age (30-34)	0.18238***	0.12922***
	(10.85)	(4.69)
Age (35-39)	0.20199***	0.17287***
	(11.58)	(6.02)
Age (40-44)	0.26421***	0.14890***
	(14.44)	(5.08)
Age (45-49)	0.29047***	0.19302***
	(15.58)	(6.53)
Age (50-54)	0.26194***	0.16740***
	(11.8)	(4.95)
Age (55-59)	0.26818***	0.17958***
	(11.68)	(4.88)
Age (60-64)	0.07484***	0.19066***
	(3.21)	(4.22)
Men	0.25883***	0.11442***
	(28.55)	(7.56)
Rural	-0.14710***	-0.16682***
	(-12.1)	(-8.44)
Secondary	0.29352***	0.12711***
	(24.23)	(5.15)
Tertiary	0.66132***	0.54534***
	(46.54)	(19.77)
Couple	0.09286***	-0,00204
	(9.75)	(-0.14)
Mining, Manuf. and Utilities	0.19576***	0.10264***
	(10.78)	(3.09)
Construction	0.13145***	0,01353
	(7.63)	(0.44)
Wholesale and retail trade	0.34894***	0.18397***
	(20.3)	(5.87)
Manager	0.70363***	0.45183***
	(34.31)	(23.88)
Professionals	0.30031***	0.48408***
	(22.08)	(12.71)
Months in Work	0.00086***	0.00105***
	(19.39)	(10.95)
Self-Employed	-0.02837**	0.05047**
	(-2.32)	(2.19)
Employer	0.48996***	0.62360***
	(14.35)	(11.81)
Region dummies	Yes	Yes
Constant	-0,03343	7.74958***
	(-1.49)	(165,74)
Observations	23564	7686
Adjusted R^2	0.4107	0.3744

Source: Authors' own calculations based on household surveys Notes: t statistics in parenthesis, significance level: * p<0.1, ** p<0.05, *** p<0.01

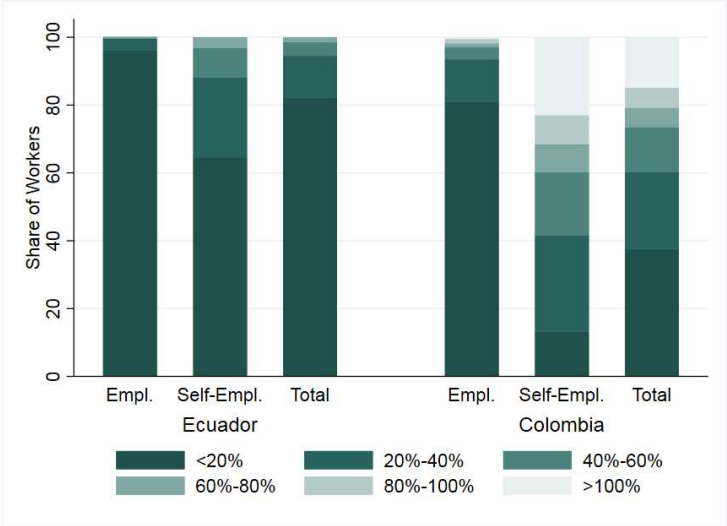
A.1.1 Formalization Tax Rates assuming no change in earnings

Figure A1.1 Formalization Tax Rates assuming no change in earnings (2014) by quintile of earnings in informality of each informal type of work



Source: Authors' own calculations based on microsimulation models

Figure A1.2 Share of workers by range of FTR assuming no change in earnings (2014)



Source: Authors' own calculations based on microsimulation models

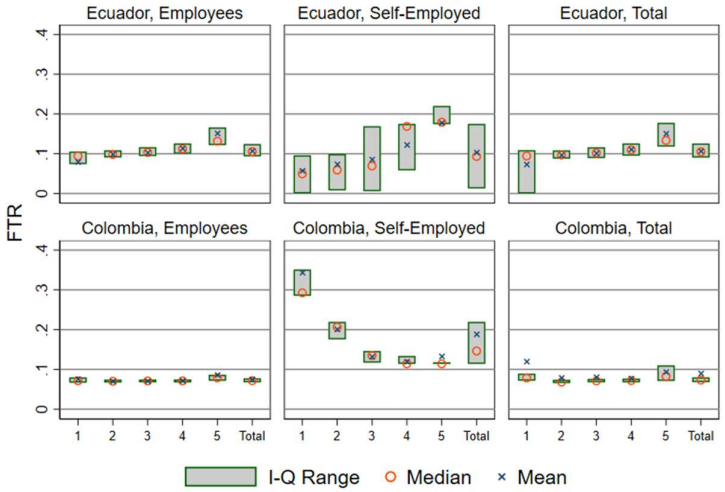
A.1.2 Incentives to formal work for formal workers

For this section we use the version of the FTR as defined in Equation 2 but move formal workers to the informal sector. The equation is:

$$FTR_i = \frac{Y^1_{h,i} - Y^0_{h,i}}{w_i}, \tag{A.1}$$

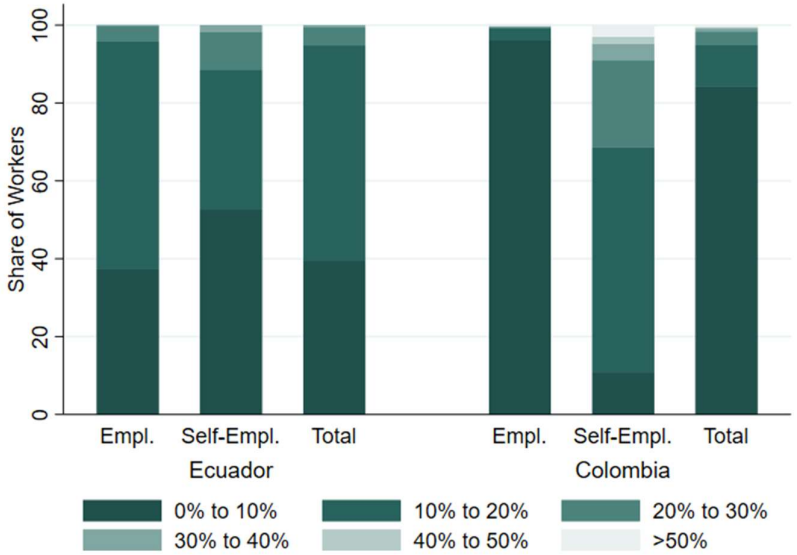
where w_i represents worker i's earnings in the formal sector and $y_{h,i}$ represents household disposable income for worker i. The superscripts 0 and 1 represent time, that is, before and after simulated movement to the informal sector takes place, respectively. Notice that we have changed the order of the subscripts relative to Equation 2. Given that there are savings associated with moving to the informal sector, the positive value should be interpreted as the burden formal workers must assume staying in the formal sector relative to moving to the informal sector.

Figure A1.3 Formalization Tax Rates, assuming no change in earnings (2014) by quintile of earnings in formality of each informal type of work



Source: Authors' own calculations based on microsimulation models

Figure A1.4 Share of workers by range of FTR assuming no change in earnings (2014)



Source: Authors' own calculations based on microsimulation models

Chapter 2: The supply of informal labour in Colombia: a microeconometric approach[1]

Abstract

Labour informality, initially analysed as a segmented market phenomenon, has more recently been studied as an optimal choice. Thus, the focus shifted from barriers that prevent informal workers from becoming formal, to the determinants of the rational choice of not being formal. This paper presents two structural modelling frameworks, The Discrete Choice (DC) and the Random Utility-Random Opportunity (RURO), and it emphasises an extended version of the RURO model which is not only able to capture restrictions on job availability but also introduces sector choice (formal-informal) allowing us to explore the two conflicting perspectives. We make a comprehensive review of the estimation procedure for the two frameworks and employ Colombian data to estimate three models of labour supply for single individuals. Overall, we find good model fit and similarities between the estimates of the DC and the simple RURO model. In the last part we use the RURO model with sectoral choice to set forth the specificities of counterfactual simulations. Using the extended version of the RURO model we find significant barriers to sectoral mobility: simulating important exogenous increases in education for informal workers or in monetary incentives in the formal sector leads to a reduced number of sectoral transitions indicating a high degree of segmentation of labour markets in developing economies.

JEL: J42, J22, H22

Keywords: Informality, labour supply, microsimulation.

[1] I would like to thank Sebastiaan Maes, Bart Capéau and André Decoster at KU Leuven (Belgium) for their guidance on the implementation of the RURO Model. All remaining shortcomings are my responsibility alone.

2.1 Introduction

The choice of being informal has received increasing attention since the works of Magnac (1991), Maloney (1999) and Pratap and Quintin (2006) provided empirical evidence on the incompleteness of classical segmented labour market theory. Hence, recent literature on informality has moved from the two-sector Harris-Todaro model (Rauch, 1991 and Loayza, 1996) to analysing conditions under which workers choose to be in the formal or informal sector (Lehmann and Pignatti, 2007; Bosch and Maloney 2006 and 2010, Lehmann et al., 2012).

With more than half the workforce in informal activities in Latin America, understanding the nature of this phenomenon is crucial for policymaking. As concisely summarised by Bosch and Maloney (2010): if workers in the informal sector show similar dynamics to the unemployed, distortions in the formal sector are indeed large and the need for reform is compelling. However, if their dynamics are similar to those of the formal sector, the focus shifts towards the cost-benefit analysis agents undertake in choosing among sectors.

Current structural labour supply models are well suited to analysing individual labour responses to simulated exogenous changes, but only under the assumption that workers are not restricted in their choices. For instance, Blundell et al., (2000) study the likely effect of introducing the working families' tax credit (an in-work support for families with children) on labour supply in the UK; Immervoll et al., (2007) study this type of in-work credits for 15 European countries; Steiner and Wrohlich (2004) simulate the potential labour supply effects of changing tax rules for married couples in Germany or Flood, Hansen, and Wahlberg (2004) study the effects of labour supply incentives for low income families in Sweden through a model that extends the labour supply choice to account for welfare participation.

Despite the potential of labour supply models to analyse labour informality, there are very few studies using these methods.[2] This could be because such models were mainly set up for developed economies where the meaningful choice is to participate in the labour market with the underlying assumption of full availability of jobs for workers at a fixed wage. Alternatively, it could be the case that the identification of the parameters on these models requires "complex" budget sets,

[2] Exceptions are Magnac (1991) and Pradhan and van Soest (1997) which will be discussed later.

especially regarding mean-tested benefits that are not present in the tax-benefit systems of most developing countries, preventing a take-off of the methodology.

Among the existing labour supply models we find the Discrete Choice (DC) model which assumes that wages are fixed and full availability of jobs. We also find the Random-Utility Random-Opportunity (RURO) model (Aaberge, Dagsvik, and Strøm, 1995 and Decoster, Capeau, and Dekkers, 2016) represents a more appropriate framework through which to analyse labour choice. This model assumes that the relevant variable is not only hours of work but also that agents choose wages and other non-pecuniary attributes. More importantly, in this framework the availability of jobs for a specific worker is constrained by personal characteristics such as education, skills or experience, making the model well suited to analysing labour informality choice. The model has been used among others to analyse sectoral choice (Dagsvik and Strøm, 2006), optimal tax-transfer rules (Colombino and Islam, 2020), tax credits (Moscarola et al., 2020), involuntary unemployment (de Boer, 2018) and labour market participation of the elderly (Capeau and Decoster, 2015).

This paper proposes the use of structural labour supply models to analyse informality in developing economies. More precisely, it presents a detailed overview of the main empirical approaches to estimate such models, the DC and the RURO, using cross-sectional data. The paper emphasises a version of the RURO model proposed by Dagsvik and Strøm (2006) and Aaberge and Flood (2013) which is able to capture restrictions on job availability and sectoral choice (formal-informal). We compare estimates for three types of models: a DC model, a simple RURO model and the RURO model with sectoral choice. Our results show that the three models have a good fit to the data and that preference estimates are similar for the basic versions of the DC and RURO models.

Moreover, to illustrate the specificities and the scope of counterfactual simulations within this framework, we analyse the effects of exogenous changes in human capital and tax-benefit rules on the labour market formal-informal distribution with the extended RURO model. Our counterfactual exercise indicates that increasing educational attainment to a tertiary education degree level for all young informal workers aged 40 or less in the sample increases both wages and formal job availability but results in a modest 6.5 percent transition of informal workers to the formal sector. Results are even less impressive for monetary incentives to formality. The almost negligible sector shift towards formal employment indicates that significant barriers for informal workers do exist. As will

be seen, there are important assumptions that we impose, and we estimate the models based on a very specific sub-group of individuals that is not entirely representative of the informal and formal workforce However, we consider the approach presented here a good starting point to the study of informal labour markets and further research with more comprehensive models could be built upon the models discussed.

The document is divided into six sections, this introduction being the first. Section 2.2 provides a review of empirical studies on labour formality choice especially on the conflicting nature of informality at the micro level. Section 2.3 presents the methodological framework of current labour supply models: the discrete choice model, the RURO model and an extended version of the latter including sectoral choice. Section 2.4 presents the data and results of the model estimates. Section 2.5 introduces policy simulations and Section 2.6 presents conclusions.

2.2 Labour formality choice

Most studies on labour formality choice are based on two-sector equilibrium models that rarely resort to microdata (Rauch, 1991; Loayza, 1996; Straub, 2005; Amaral and Quintin, 2006; Loayza and Rigolini, 2011). More recent papers on informality choice build on this equilibrium framework but take market frictions into account following the search and matching approach pioneered by Diamond (1982) and Mortensen and Pissarides (1999) (see Zenou, 2008; Satchi and Temple, 2009, Albrecht et al., 2009; Bosh and Maloney, 2010 and Bosch and Esteban-Pretel, 2012). However, this literature on labour formality choice relies extensively on a priori assumptions on the dynamics of labour markets and has not considered the interplay of individual characteristics and sectoral choice. In the following we discuss five important microeconometric contributions to the study of informality choice that improve on these features.

Magnac (1991) tests the hypothesis of labour market segmentation between formal and informal sectors, comparing estimates of a competitive equilibrium model (free movement between sectors) with those of a segmented model with a cost of entry into the formal sector (queuing for a formal job).[3] Both models are bivariate tobits including sector choice and wages but omitting hours of

[3] Formal sector comprises employees and informal sector comprises self-employed workers excluding employers (Magnac, 1991).

work. Using labour data for women in urban areas of Colombia, he finds that the hypothesis of competitive equilibrium cannot be rejected.

Improving on Magnac (1991), Pradhan and van Soest (1995) study labour formality choice with ordered probit models (i.e., informal sector is inferior for workers) and multinomial logits (there is no ordering of sectors) estimated for Bolivian workers. By explicitly including non-participation and modelling the effect of sector selection on wages, they conclude that multinomial logits (free movement) are preferred for women while ordered probits are preferred for males (segmentation).

Using the same dataset for Bolivia, Pradhan and van Soest (1997) study informal-formal allocation for couples using an extended version of a structural labour supply model proposed by Ransom (1987).[4] Sector selection and hours of work are based on sector-specific wages which depend on observable characteristics. Non-observable non-monetary returns of being in the formal sector are explicitly modelled relative to the monetary wage. The estimated non-monetary returns of formal employment are found to be mostly positive. Simulations indicate that a 10 percent decrease in wages for men increases hours worked by their partners by around 2.5 percent, but a similar decrease in women wages has hardly any effect. On the other hand, a 10 percent decrease in formal sector wages moves 2.1 percent of male workers from the formal to the informal sector and increases female participation by 0.4 percent.

The model proposed by Pradhan and van Soest (1997) is the one most in line with ours. We improve on it by taking into account job availability and a more flexible and explicitly estimated utility function which allows easy simulation of sector responses to exogenous changes.[5] However, there are two important aspects of their model that we do not incorporate explicitly: non-pecuniary attributes and couples' sector choice. These are known features of labour markets in developing economies, where formal workers receive health and risk insurance among other non-monetary benefits, but also where working wives tend to benefit from their husbands' formal status (i.e. they are entitled to health insurance) and the flexibility of informal employment arrangements. These two aspects represent a future line of research for our framework.

[4] Formal sector comprises employees, independent professionals, and self-employed workers with household-related business assets greater than 15.000 Bolivianos (USD$ 5500). Informal sector comprises remaining self-employed workers (Pradhan and Van Soest, 1997).

[5] Pradhan and van Soest (1997) instead use first order conditions which are more cumbersome.

Lastly, Maloney (1999) and Gong, van Soest and Villagomez (2004) use panel data for Mexico to explore determinants of transitions between formality and informality with multinomial models. The first author uses a multinomial logit for three sectors: self-employed, informal employees and formal employees. He suggests that overall, there is a high degree of mobility between sectors. Secondly, the length of tenure is similar for all sectors, implying that workers do not arrive in the formal sector and stay there until retirement, as would be the case under segmentation. Lastly, workers out of formal employment do not seem to be queuing for jobs in this sector because higher experience is not observed to determine transition to the formal sector. Improving on Maloney (1999), Gong, van Soest and Villagomez (2004) use a dynamic multinomial logit model with random effects and explicitly consider unobservable factors. Their study comprises three sectors: non-working, formal and informal. Despite finding strong state persistence, a test for symmetry of movements between sectors (non-segmentation) could not be rejected.

2.3 Labour supply models

Throughout this paper, we are interested in introducing new methodological tools to study labour supply decisions, especially, in the presence of informal labour markets. Moreover, as we focus on a supply perspective, we would like to avoid assumptions on the dynamics of labour markets such as those of the equilibrium framework. We are also interested in allowing the model to incorporate population heterogeneity by keeping the analysis at the micro level. In that sense, building a structural model with sectoral choice such as Pradhan and van Soest (1997) seems to be the more reasonable approach.

We build on the current labour supply literature which follows the Random Utility type of models (RUM) started by McFadden (1973), with applications to labour supply pioneered by van Soest (1995). By focusing on the estimation of the utility function, this methodology avoids the difficulties faced by reduced form models (Kosters, 1966, Bowen and Finegan, 1969 and Hall, 1970) and the structural 'marginalist' methodology (Heckman 1974, Burtless and Hausman, 1978, and Zabalza,

1983).[6] We could easily classify the papers of Magnac (1991) and Pradhan and van Soest (1997) in the latter group.

This approach has several advantages: (i) it is possible to have non-convexities in the tax and benefit system,[7] (ii) simulation is possible because the model separates preferences from policies, (iii) couples' joint decision is simpler to analyse, (iv) it is feasible to incorporate preference heterogeneity on leisure or consumption, and (v) it is possible to include more than two goods in the utility function (Flood and Islam, 2005).

As highlighted by Aaberge and Colombino (2014), random utility labour supply models can be classified into two groups. The first one consists of Discrete Choice (DC) models, which assume that wage (productivity) for each agent is fixed, therefore, disposable income is entirely determined by the discrete set of working time regimes an agent chooses from. The second group comprises Random Utility-Random Opportunity (RURO) models, which assume that there is a stochastic process by which jobs packages, consisting of a time regime, a wage, and other attributes, arrive to each agent. We now turn to the mechanics of these models and in section 2.4, we present the results of their estimation for Colombia.

2.3.1 Discrete Choice Labour Supply (DC)

In the basic DC labour supply model, agents have a stochastic direct utility function (U_i) over one consumption good (C_i) and hours of work (L_i):

$$U_i = U(V(C_i, T - L_i|X), \varepsilon_i) \tag{1}$$

Where the subscript i represents a possible choice, the functional form of the systematic part of the utility function V is defined a priori by the modeller, ε_i is an error term with an Extreme (Maximum) value Type I distribution, one different for each choice.[8] T is total available time and X is a

[6] The term structural 'marginalist' is used by Aaberge and Colombino (2014) in a historical review of labour supply estimation. It refers to models that impose the conditions of a constrained maximisation problem of labour supply into reduced form estimates.

[7] For instance, those arising from several kinds of benefits.

[8] In the DC model the error term is assumed to be additive. For the RURO model it is assumed to be multiplicative. The extreme value type I distribution, also referred to as a Gumbel or double exponential, has pdf: $f(\varepsilon_i) = e^{-\varepsilon_i}e^{-e^{-\varepsilon_i}}$ and cdf: $F(\varepsilon_i) = e^{-e^{-\varepsilon_i}}$ Since the distribution has a mean of $\mu = 0.5772$ and standard deviation $\sigma = 1.2825$ no further parameters need to be estimated.

vector of individual characteristics such as age, gender, education or number of children, that could directly affect preferences or indirectly affect consumption (i.e. through disposable income).

The crucial assumption in DC models is that the choice set of hours worked consists of only k discrete alternatives: $L_i \in [0, T] \; \forall \; i = 1,2, \ldots k$. That is, agents cannot vary hours worked continuously but instead, they choose the best option from a smaller set, which is constrained by the total time endowment. As a result, none of these alternatives represents the traditional tangency solution of a maximisation problem (Creddy and Kalb, 2005). Moreover, DC models assume that each worker's wage is fixed (i.e. hourly wage does not change with hours worked), thus, disposable income is a function of hours worked only, and the wage is subsumed into the vector of characteristics X.

For simplicity, agents do not save (or equally, savings are considered as a part of consumption), therefore, assuming a normalised price for the only physical good in the model, consumption coincides with disposable income. Equation 2 presents consumption (C_i) as a function $f(.)$ that translates each discrete set of hours worked (L_i) and a fixed wage (w) into disposable income for that choice by adding benefits and subtracting taxes and social insurance contributions (the function $TB(.)$) from labour (wL_i) and non-labour (Y) market income. As most modern tax and benefit systems are rather cumbersome, it is almost impossible to directly include $f(.)$ in the model. Thus, without loss of generality, disposable income is computed for each element in the discrete set of hours worked by means of a tax and benefit microsimulation model.

$$C_i = f(L_i|X) = wL_i + Y + TB(wL_i + Y|X) \tag{2}$$

As shown by McFadden (1973) and Creddy and Kalb (2005) under the previous assumptions, the probability that the chosen time regime L_i is the observed, is given by the traditional multinomial logit expression (Eq. 3) and preference parameters of the utility function could be estimated using the maximum likelihood method under the additional assumption that decisions are made by each agent independently of others.

$$p(L_i|X) = \frac{e^{v(L_i|X)}}{\sum_{j=1}^{k} e^{v(L_j|X)}} \tag{3}$$

Three additional remarks are in order: first, as is the case with observational data, the modeller cannot observe wages for non-workers, thus, their wages are usually imputed. Second, for some observations labour supply decisions are not agent-independent, for instance those of couples. In this case, a unitary decision-making model is usually assumed, where the utility function of the household includes individual labour supplies, one consumption good (equivalent to household disposable income) and the choice set is a combination of the discrete hours of each couple member. Lastly, as pointed out by van Soest (1995), the model may require some fixed costs of participating in the labour market to provide a better fit to the data.[9] These costs are usually added as disutility terms in the utility function if working hours are positive.

2.3.2 Labour supply in Random Utility-Random Opportunity models (RURO)

The basic RURO model (Aaberge, Dagsvik and Strøm, 1995 and Aaberge, Colombino and Strøm, 1999) can be thought of as a generalisation of the DC framework in which, on the one hand, wages are not a characteristic of each agent, but part of a job offer alongside the time regime. On the other hand, utilities in the multinomial logit likelihood are weighted with the intensity with which job offers and non-market activities are made available to each agent (Decoster, Capeau and Dekker, 2016). In other words, if the DC model focuses on labour supply, the RURO allows us to study labour market participation taking into account labour supply and labour demand simultaneously.

More specifically, in a RURO model each job offer is a bundle consisting of working time (L_i) and wage offered by the employer (w_i). Each non-market activity is assumed to offer a zero wage ($w_i = 0$) and to require no hours of work ($L_i = 0$). For notational simplicity, these two variables are used as the arguments of the utility function $V(.)$ instead of consumption and leisure.

The arrival of a job offer with a value of ε_i (error term in the utility function in Equation 1) to an agent is assumed to depend on personal characteristics, labour demand conditions, but especially on the wage and time regime the job offer stipulates. This arrival process is modelled in the RURO by an inhomogeneous spatial Poisson process, with intensity parameter given by:[10]

[9] The basic model usually overpredicts part-time hours of work; hence, a penalty for positive working hours could reduce the probability of this time regime being chosen (Creddy and Kalb, 2005).

[10] A Poisson process is said to be inhomogeneous if the intensity parameter Λ depends on the moment of measurement t ($\Lambda(t)$).

$$\Lambda = \lambda(\varepsilon_i, q|X_q)g_1(w_i|X_w)g_2(L_i) \tag{4}$$

The intensity function λ of working alternatives has the form:

$$\lambda(\varepsilon_i, q|X_q) = \frac{q(X_q)}{\varepsilon_i^2} = \frac{e^{\beta_q X_q}}{\varepsilon_i^2} \tag{5}$$

where $q(X_q)$ is a function of personal characteristics (X_q) and labour demand conditions for worker's attributes that increases the availability of job offers relative to non–market alternatives. The variables X_q are weighted by a vector of coefficients to be estimated β_q. The function g_1 is the density of job offers paying hourly wages w_i which is assumed to be lognormal and to depend on personal attributes (X_w). The function g_2 is the density of jobs requiring L_i hours of work which is assumed piecemeal uniform with peaks in the most frequently observed time regimes: full-time, part-time, etc. Analogously, the intensity parameter of arrival of non-work alternatives is $\Lambda = \frac{1}{\varepsilon_i^2}$

As shown by Capeau and Decoster (2015), the resulting individual probability that the time regime $L_i > 0$ and wage $w_i > 0$ are the observed is given by the expression:

$$p(w_i, L_i) = \frac{q(X_q)g_1(w_i|X_w)\, g_2(L_i)\, e^{V(w_i,L_i)}}{e^{V(0,0)} + \int_{w_j \in \mathbb{W}} \int_{L_k \in \mathbb{H}} q(X_q)g_1(w_j|X_w)\, g_2(L_k)\, e^{V(w_j,L_k)}\, dL_k\, dw_j} \tag{6a}$$

where $\mathbb{W}$ and $\mathbb{H}$ are the sets of wage offers and hours of work, respectively. In the case of observing a non-working individual, the likelihood has the form:

$$p(0,0) = \frac{e^{V(0,0)}}{e^{V(0,0)} + \int_{w_j \in \mathbb{W}} \int_{L_k \in \mathbb{H}} q(X_q)g_1(w_j|X_w)\, g_2(L_k)\, e^{V(w_j,L_k)}\, dL_k\, dw_j} \tag{6b}$$

There is a noticeable resemblance between the RURO likelihood and the multinomial logit expression in Equation 3. However, some important differences arise. Firstly, in RURO we do not discretise hours of work to k points but consider the entire distribution of hours available. Given the piecemeal nature of the hours density, RURO overcomes the DC framework need for utility costs of working. It does so by assuming that some institutional exogenous process makes full-time or half-time regimes more abundant (likely) than other working arrangements. In other words, if we

assume no demand restrictions, some workers would prefer an alternative time regime, but given that we consider a lower availability of jobs with atypical time regimes, this choice will reduce utility.

Secondly, in RURO wages are not fixed and instead we consider the entire density of wages. However, the higher degree of freedom on this side of the model requires aligning wages to each worker's productivity. RURO overcomes this problem by assuming that given some fixed worker characteristics, a higher wage than the one observed is less likely to be available; therefore, given that utilities are weighted by wage availability, worker's utility will be lower under a different wage than under wages more in line with personal characteristics.

Lastly, given that the model takes non-work into account, the q function captures the availability of job offers relative to non-working alternatives. For this function, some personal characteristics known a priori to determine participation rates such as age or gender will modify the availability of job offers relative to non-work and will improve the model fit between the two options.

2.3.3 Labour supply and sectoral choice: an extended RURO (RURO-SC)

Considering that the RURO model takes the availability of job offers into account, we extend this framework to include sector choice (z), with $z = 0\ (\text{informal})$, $z = 1\ (\text{formal})$ and $z = .\ (\text{non} - \text{work})$. In this way, the sector choice is analysed under possible demand side restrictions, as could be the case of labour markets in developing countries. Under the additional assumption that job offer intensities, wage and hours densities are sector specific, the intensity parameter of the Poisson process for the arrival of a job offer with wage w_i and time regime L_i in sector z is given by: [11]

$$\Lambda_z = \frac{q_z(X_{q,z})}{\varepsilon_i^2} g_{1z}(w_i|X_{w,z}) g_{2z}(L_i) \ \text{ for } z = 0,1 \tag{7}$$

The individual likelihood of observing an individual with such a job offer (w_i, L_i, z) is:

[11] Dagsvik and Strøm (2006) introduce a RURO with sectoral choice between public and private sectors in a model estimated for Norway. Aaberge and Flood (2013) also introduce this likelihood under the additional choice of benefit take-up for single mothers in Sweden.

$$p(w_i, L_i, z) = \frac{q_z(X_{q,z})\, g_{1z}(w_i|X_{w,z}) g_{2z}(L_i)\, e^{V(w_i,L_i,z)}}{e^{V(0,0,.)} + \sum_{m=0}^{1} \int_{w_j \in \mathbb{W}} \int_{L_k \in \mathbb{H}} q_m(X_{q,m}) g_{1m}(w_j|X_{w,m}) g_{2m}(L_k)\, e^{V(w_j,L_k,m)} dL_k dw_j} \quad (8a)$$

While the likelihood of observing a non-working $(0,0,.)$ individual is given by:

$$p(0,0,.) = \frac{e^{V(0,0,.)}}{e^{V(0,0,.)} + \sum_{m=0}^{1} \int_{w_j \in \mathbb{W}} \int_{L_k \in \mathbb{H}} q_m(X_{q,m}) g_{1m}(w_j|X_{w,m}) g_{2m}(L_k)\, e^{V(w_j,L_k,m)} dL_k dw_j} \quad (8b)$$

Notice that in this very general functional form, we allow sectoral differences for preferences and hours densities. We also allow for the covariates entering the intensity function q_z and the wage offer density g_{1z} to be different between sectors.

2.3.4 Estimation

In DC models we first define the number of choices or bins (k), the size of each bin and the time regime each bin represents. Next, we estimate the wage for non-workers. Most of the time this is done with a Mincer equation using a first stage Probit in a Heckman selection model of participation.[12] We compute disposable income for the k hour points using the estimated wage for non-workers and the observed wage for workers.[13] Lastly, we estimate the likelihood function given by Equation (3).

In the case of the RURO models, hours are not discretised, and wages are not given. However, we do not observe the entire set of wages $(\mathbb{W})$ and of hours worked $(\mathbb{H})$. Hence, to estimate the likelihood function, we rely on a subset of alternatives $\mathbb{D}$ drawn from a priori density functions (i.e. simulated maximum likelihood). For the next part we focus on the extended version of the RURO model, however the simpler version is estimated in a similar manner. Applying the estimation insights in Capeau and Decoster (2015) to the sectoral choice model, we first calculate the proportion of each sector in the sample: informal work (π_0), formal work (π_1) or non-work (1- $\pi_0 - \pi_0$). Next, we compare these proportions with a random draw from a uniform density to determine the

[12] Notice that the selection model for participation presented here differs from the one discussed in the previous chapter which focused on the choice between formal and informal work.

[13] In some cases, researchers use predicted wages for the whole sample.

sector. Third, in the case of working, we draw hourly wages from a log-normal density specific to each sector, with mean μ_z and standard deviation σ_z observed in the sample. Fourth, in the case of working, we draw hours of work from a uniform distribution on the $[H_{min}, H_{max}]$ support. Fifth, given the wage and hours worked we compute disposable income for each draw. This last step is also taken for the observed alternative.

As highlighted by Train (2009), the observed choice must be included in the set of alternatives. Moreover, the probability used to draw a job offer when creating the data for the simulation is included in the likelihood to account for a drawing process based on densities different from the true ones. More formally, a sampling component (i.e. probability of a job offer being drawn) $\mathbb{P}(w, h, z)$ contingent on sector is given by:

$$\mathbb{P}(w,h,z) = \begin{cases} 1 - \pi_0 - \pi_0 & \text{if } (w_i, h_i, z) = (0,0,.) \\ \frac{\pi_0}{H_{max} - H_{min}} \text{Lognormal}(w_i|\mu_0, \sigma_0) & \text{if } w_i > 0 \;\&\; h_i \in [H_{min}, H_{max}] \;\&\; z = 0 \\ \frac{\pi_1}{H_{max} - H_{min}} \text{Lognormal}(w_i|\mu_1, \sigma_1) & \text{if } w_i > 0 \;\&\; h_i \in [H_{min}, H_{max}] \;\&\; z = 1 \end{cases} \tag{9}$$

The simulated individual likelihood for the observed time regime $L_i > 0$ and wage $w_i > 0$ becomes:

$$p(w_i, L_i, z) = \frac{\frac{\mathbb{P}(0,0,.)}{\mathbb{P}(w_i, L_i, z_i)} q_z(X_{q,z})\, g_{1z}(w_i|X_{w,z}) g_{2z}(L_i)\, e^{V(w_i, L_i, z)}}{e^{V(0,0,.)} + \sum_{w_j, L_k, m \in \mathbb{D}} \frac{\mathbb{P}(0,0,.)}{\mathbb{P}(w_j, L_k, m)} q_m(X_{q,m})\, g_{1m}(w_i|X_{w,m}) g_{2m}(L_i)\, e^{V(w_i, L_i, m)}} \tag{10a}$$

And in the case of observing non-participation:

$$p(0,0,.) = \frac{e^{V(0,0,.)}}{e^{V(0,0,.)} + \sum_{w_j, L_k, m \in \mathbb{D}} \frac{\mathbb{P}(0,0,.)}{\mathbb{P}(w_j, L_k, m)} q_m(X_{q,m})\, g_{1m}(w_i|X_{w,m}) g_{2m}(L_i)\, e^{V(w_i, L_i, m)}} \tag{10b}$$

2.3.5 Simulation

For simulation and model fit, predicted choices result from the comparison of utilities between available alternatives. We follow Duncan and Weeks (2000) and take into account the stochastic nature of the model as follows: first, we draw random values from the Extreme Value distribution; second, we compute utility U_i with the estimated coefficients, vectors of characteristics and the stochastic component ε_i; third, we find the optimal choice (maximum U_i) for each person.

In the case of the DC model, each option i represents one of the discrete points considered. In the case of RURO models, we need a new set of alternatives from which to choose according to the parameters estimated for the Poisson process. Therefore, we follow Decoster, Capeau, and Dekkers (2016). First, we compute the likelihood of non-working, working as informal and working as formal ($1-\pi_0-\pi_1, \pi_0, \pi_1$, respectively) using the estimated $q_z(X_{q,z})$ functions. Notice that these probabilities depend on personal characteristics and opportunities estimates as opposed to the proportions used for estimation.[14] Second, these probabilities are compared with random draws from a uniform distribution. Third, in the case the draw i belongs to a working alternative in sector z, we draw hourly wages and hours from the sector specific estimated lognormal and piecemeal hours densities, respectively. Fourth, we use these wages and hours of work to compute the values of leisure and disposable income. Lastly, for each individual, we compare alternatives and select the one with the highest utility, taking into account the unobserved component of utility ε_i. For comparisons between baseline and counterfactual, the unobserved component of each draw remains constant.

2.3.6 Overview

Note that in the DC framework we estimate a utility function, and we use it to measure to what extent each individual is willing to exchange leisure for consumption assuming an exogenous wage. Simulations in the DC model are thus restricted to exogenous changes on the wage or other elements of the budget set or in rare occasions to estimated taste-shifters. In the RURO model, on top of preferences, we additionally estimate the process by which alternatives arrive to each individual, a process that we assume to be stochastic. An individual must choose one element from a set of opportunities (possible activities to do including non-working and different job offers) that is available to him. In that sense, simulations in the RURO framework are extended to include changes in the estimated parameters that govern the job arrival process (the elements of this set), that could be considered as changes in the labour demand.

[14] Recall that the q function for non-working alternatives is 1. We define $\pi_i = \frac{q_i}{1+q_0+q_1}$.

2.4 Data and empirical results

2.4.1 Data and definitions

Our analysis is based on representative household survey data from Colombia. Like many Latin-American and other developing countries, a large share of the workforce in Colombia is in informal employment with an unconditional labour informality rate at the population level of around 63 percent for 2016.[15] Most of the economic literature for the country points to the effect of market regulations reducing labour demand as the factor responsible for the high share of informal work. Based on this notion, important policy reforms benefitting firms were carried out in the country recently with limited success.

The data used in our estimation comes from the Great Integrated Household Survey for 2016 (Gran Encuesta Integrada de Hogares, GEIH). The survey contains detailed information on employment, income from different sources, as well as household and personal characteristics needed for the tax-benefit model (COLMOD) employed to measure disposable income for each alternative.[16] GEIH is the main labour force survey in the country and is carried out on a monthly basis. The data for 2016 comprises 774,693 individuals with 81.1 percent of them of working age (12 years or more in Colombia) and 49.3 percent of them participating in the labour market. There are 339,929 individuals working with 38.7 percent of them working in the formal sector.

We focus on single people aged 18-60, not in education nor disabled, and living in urban areas. Despite its empirical attractiveness, we omit couples given the difficulty of estimating a unitary decision model involving two sectors and non-work. Single people must be living without other working age household members. They are either working as employees (formal or informal) or not working, that is, the self-employed are excluded.[17] If working, they report only one job of less than

[15] In what follows we define informality as non-affiliation to social security because of the connection of social insurance contributions to the design of the tax-benefit system, and more directly to disposable income as defined in Equation 2.

[16] COLMOD combines detailed coded policy rules with microdata via the EUROMOD software to simulate direct taxes, social insurance contributions and cash transfers, see Rodriguez (2018). For the model using GEIH, expenditures were imputed given the lack of data in the GEIH. This imputation has negligible effects on disposable income as expenditures only affect income tax, which in turn is almost non-binding for the whole population.

[17] Despite more than 50% of informal workers in Colombia observed as being in self-employment, the lack of adequate data on earnings for those self-employed and also, the lack of a robust method to capture their working choices is well established in the labour supply literature.

120 hours per week. Lastly, we exclude households with unreliably low income.[18] Under these conditions, 15,347 observations remain for the estimation, 4.5 percent of the original sample.

Admittedly, the abovementioned sample selection is restrictive in important ways: as discussed in the empirical literature, an important dimension when analysing labour informality is the couple's decision (Pradhan and van Soest, 1997) whereas we focus on singles. Note also that the models are estimated for employees who are a very specific sub-group of workers that is not entirely representative of the informal and formal workforce, especially considering that in developing countries (including Colombia) informality is mainly associated with self-employment. However, the purpose of the analysis presented here is to set up the basis for the study of segmented labour markets using structural labour supply models, which could serve to build more comprehensive models including self-employed workers and couples in the future.

Table 2.1 Descriptive statistics for the estimation sample

Description	Not Working	Informal Workers	Formal Workers	Total
Observations	3,236	3,268	8,843	15,347
Average age (years)	39.3	36.5	37.6	37.7
Share Male	0.205	0.361	0.403	0.352
Share having 0-2-year-old children	0.114	0.054	0.043	0.060
Share having 3-4-year-old children	0.071	0.058	0.044	0.052
Share having 5-10-year-old children	0.212	0.183	0.163	0.178
Share having 11-18-year-old children	0.205	0.217	0.202	0.206
Share in Bogota	0.029	0.064	0.086	0.069
Share with Higher Education	0.278	0.145	0.526	0.393
Share with Primary Education or less	0.202	0.263	0.056	0.131
Share Vulnerable	0.040	0.048	0.009	0.024
Hourly wage* (COP**)	-	3,660	7,576	5,145
Weekly hours of work	-	48.46	48.21	38.1
Disposable Income (million COP**)	0.84	0.96	1.72	1.37

Source: Authors' calculations based on GEIH (2016) *Conditional on working, **Colombian pesos. [19]

Table 2.1 present some descriptive statistics for the estimation sample. Most of these variables will help the identification of the model. We observe that the target group is composed predominantly

[18] We exclude households with observed monthly disposable income per person below half the extreme poverty line. That is $57.000 COP (approx. US$19 per month). This reduces the original sample by around 2,455 observations or 16% of the final sample. Without this assumption we are not able to identify the parameters of the RURO-SC model, possibly because these extremely poor households do not align with the setup of the model.

[19] 1 $USD= 3.038 COP (exchange rate of 1 June 2016).

of females (65 percent) especially given their high share of the not-working category (80 percent). Workers are on average younger than non-workers and have fewer children. For the entire survey, Bogota (Colombia's capital) represents 19 percent of total workers, for the sample, a lower share lives in the city (6.9 percent of the sample: 6.4 percent of informal and 8.6 percent of formal workers).[20]

The sample is on average more educated than the other survey respondents. In the survey, 19 percent of those aged 18 or over had higher education relative to 39.3 percent in the sample. Hourly wages are on average almost twice as high in the formal sector than in the informal, with disposable incomes following a similar pattern. In the sample, non-workers have an average income slightly below that of informal workers. Lastly, there is a significantly lower share of vulnerable individuals in the formal sector relative to the informal and not-working groups.[21]

2.4.2 Estimation assumptions

Based on the distribution of hours worked observed in the country, for the DC model we assume 10 hours points: [0, 10.5, 27.5, 40, 50, 60, 72.5, 85, 95, 110] with cutting points at [0, 1, 20, 35, 45, 55, 65, 80, 90, 100, 120] and the total available time to be $\mathsf{T} = (24\mathrm{hr})(7\mathrm{days}) = 168$. We estimate wages for non-working individuals using a Mincer equation within a two-stage Heckman estimation that corrects for selection into work.[22]

We make 100 draws for the RURO and 200 draws for the RURO with sectoral choice, twice as many to account for the two sectors. We also assume the hours support is in the interval $[\mathsf{H}_{\mathsf{min}}, \mathsf{H}_{\mathsf{max}}] = [1{,}120]$. Lastly, we assume three peaks in the piecemeal uniform density at 40, 48 and 60 hr/w, trying to capture the most common available time regimes observed in the Colombian data. Each peak is one hour wide around these three values.

[20] This result is mainly driven by population weights.

[21] We define as vulnerable population those observations belonging to the first quintile of a composite life quality index usually employed in Colombia (ICV). The index includes 12 well-being dimensions such as: quality of roofs, walls and floors, access to sanitation and water, and human capital of the household.

[22] Estimates of these models are shown in the appendix. In this case

Deterministic utility function

For the three models, we assume the deterministic component of the utility function to be of the Box-Cox type given the high flexibility of its functional form but also because of other important properties highlighted in the literature.[23] The utility function follows the specification:

$$V(C_i, T - L_i|X) = V(w_i, L_i) = (\beta'_H X_H)\left(\frac{\left(\frac{T - L_i}{T}\right)^{\alpha_H} - 1}{\alpha_H}\right) + (\beta'_Y X_Y)\left(\frac{Y_i{}^{\alpha_Y} - 1}{\alpha_Y}\right) \qquad (11)$$

Where X_H and X_Y are a vector of parameters that shift the intensity of preference for leisure and consumption, the exponents α_H and $\alpha_Y < 1$ determine the curvature of the indifference curves, with lower values implying less substitutability between leisure and income. $\alpha_H, \alpha_Y, \beta_H, \beta_Y$ are parameters to be estimated. Y_i is monthly disposable income in millions of Colombian pesos and L_i is weekly hours of work. Notice that sector does not enter utility because we were not able to identify the parameters of the model when we included sectoral preferences. We acknowledge that the omission of the sector in the utility function is important because non-monetary benefits of a formal job are valued by workers and future research should address this point. The analysis in this paper should therefore be considered as a first step for the development and improvement of future RURO frameworks for the analysis of labour supply in the presence of informality.

2.4.3 Estimation results

The estimated coefficients for the three models are presented in Table 2.2 below. We observe a lower preference for leisure for single males, but higher for single people with children aged 0-2. The intensity of preference for leisure decreases with age. For the three models, most of the taste-shifters are statistically significant. The α_H and α_Y coefficients are always negative and statistically significant, being the lowest for the RURO-SC model. This implies that taking restrictions in job availability into account dramatically changes preferences, making leisure and income less substitutable. For the DC model the utility cost of work decreases with age, but this effect is marginally decreasing. Both coefficients for age are statistically significant.

[23] See Dagsvik (2006).

Table 2.2 Models of Labour Supply Estimates for Colombia (2016)

		Variable	DC	RURO	RURO-SC
Preferences All	Leisure	constant	17.8697***	22.5285***	2.8119***
			(5.3)	(4.85)	(4.72)
		male	-0.5428***	-0.7807***	-0.0604***
			(-11.26)	(-10.74)	(-5.81)
		age	-8.9689***	-11.8294***	-1.5861***
			(-4.71)	(-4.5)	(-4.68)
		age2	1.314***	1.7518***	0.2325***
			(4.9)	(4.71)	(4.81)
		child 0-2y	0.1077	0.2332*	0.1596***
			(0.997)	(1.67)	(4.09)
		child 3-4y	-0.2693***	-0.3274**	0.0365
			(-2.73)	(-2.54)	(1.46)
		child 5-10y	-0.2611***	-0.3192***	0.0402***
			(-4.26)	(-3.86)	(2.79)
		alfa	-2.6465***	-1.9972***	-5.1191***
			(-35.44)	(-20.87)	(-33.2)
	Income	constant	2.4429***	2.2202***	0.0025*
			(52.39)	(41.45)	(1.63)
		alfa	-0.1486***	-0.0614***	-2.4294***
			(-13.16)	(-3.52)	(-9.39)
	Fixed-Cost	constant	53.058***		
			(13.83)		
		child 0-5y	-0.1099		
			(-1.37)		
		age	-28.8029***		
			(-13.27)		
		age2	4.0986***		
			(13.43)		

		Variable	RURO	RURO-SC
Opportunities-All		constant	-32.7137***	
			(-8.01)	
		age	15.0365***	
			(6.51)	
		age2	-2.1278***	
			(-6.55)	
		lower edu.	0.8612***	
			(7.07)	
		higher edu.	-1.5509***	
			(-9.37)	
		male	-0.4328***	
			(-5.4)	
		form rate	3.7024***	
			(9.36)	
		vulnerable	-0.4778***	
			(-3.11)	
Opportunities-Informal		constant		-29.6702***
				(-9.05)
		age		14.612***
				(7.86)
		age2		-2.1391***
				(-8.16)
		lower edu.		0.2125***
				(2.96)
		higher edu.		-0.6137***
				(-8.96)
		male		0.5114***
				(8.34)
Opportunities-Formal		constant		-69.7434***
				(-22.57)
		age		35.9483***
				(20.63)
		age2		-5.034***
				(-20.6)
		lower edu.		-0.4583***
				(-4.98)
		higher edu.		-0.1307
				(-1.29)
		male		0.8899***
				(15.96)
		form rate		3.1778***
				(13.24)
		vulnerable		-0.8209***
				(-5.63)

Table 2.2 Models of Labour Supply Estimates for Colombia (2016) (Continued)

	Variable	RURO	RURO-SC
Wage Offer-All	constant	7.0504***	
		(273.79)	
	experience	1.6632***	
		(8.94)	
	experience2	-2.7171***	
		(-6.85)	
	lower edu.	-0.2589***	
		(-11.31)	
	higher edu.	0.5706***	
		(40.79)	
	male	0.0311**	
		(2.49)	
	Bogota	0.1189***	
		(5.58)	
	formal	0.5466***	
		(37.31)	
	rmse	0.5839***	
		(123.12)	
Wage Offer-Informal	constant		7.7636***
			(223.34)
	experience		0.7261**
			(2.37)
	experience2		-1.2578**
			(-2.08)
	lower edu.		-0.2446***
			(-8.43)
	higher edu.		0.4775***
			(15.78)
	male		0.2453***
			(11.1)
	Bogota		0.2121***
			(4.96)
	rmse		0.5788***
			(78.18)
Wage Offer-Formal	constant		8.1519***
			(310.88)
	experience		1.2434***
			(4.96)
	experience2		-1.6483***
			(-2.91)
	lower edu.		-0.3288***
			(-9.33)
	higher edu.		0.6246***
			(41.54)
	male		0.0668***
			(4.53)
	Bogota		0.0842***
			(3.32)
	rmse		0.606***
			(123.21)

	Variable	DC	RURO	RURO-SC
Hours-All	peak 1 (40 h/w)		3.1234***	
			(96.49)	
	peak 2 (48 h/w)		3.936***	
			(148.93)	
	peak 3 (60 h/w)		2.1086***	
			(47.77)	
H.-Informal	peak 1 (40 h/w)			2.6071***
				(41.79)
	peak 2 (48 h/w)			3.3911***
				(72.48)
	peak 3 (60 h/w)			2.4818***
				(36.57)
H.-Formal	peak 1 (40 h/w)			3.678***
				(108.92)
	peak 2 (48 h/w)			4.7126***
				(173.5)
	peak 3 (60 h/w)			2.6041***
				(49.93)
	Observations	15,347	15,347	15,347
	Log-Likelihood	-24,305.8	-43,047.3	-56,565.2

Source: Authors' calculations based on GEIH (2016) Notes: t statistics in parenthesis, significance level: * p<0.1, ** p<0.05, *** p<0.01

In the RURO type of models, coefficients for wage offers, hours densities and opportunities are mostly statistically significant. In the case of wage offer densities, all the signs are as expected. For the three densities, the effect of experience on wages is concave, living in Bogota or having tertiary education increases hourly income, and, in the case of the simpler RURO, being in the formal sector

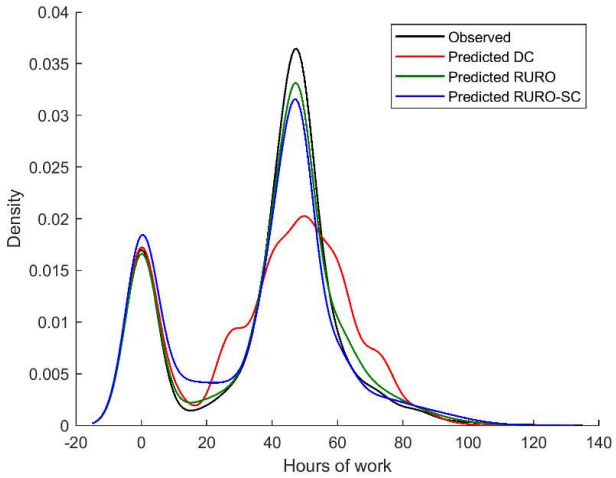
increases wages.[24] Hours peaks are very significant in both models with a higher peak for full-time (48hr/w) and a higher dispersion of hours in the informal sector as in the data.

Turning to the opportunities function, in all cases the effect of age on the availability of job offers is positive but marginally decreasing. A similar concave effect is found for education; a higher availability of working relative to non-working opportunities is found for those who completed high school; those who only completed primary or completed a degree or vocational training receive fewer working opportunities relative to the former group. The effect is similar across all RURO models, albeit the negative effect of higher education on opportunities in the formal sector is not statistically significant. Lastly, a higher group-specific formalization rate increases opportunities in the formal sector while being in a vulnerable household decreases formal opportunities.[25]

Model Fit

Figure 2.1 presents the fit of the model for hours worked. All models do a good job predicting weekly work time. However, the DC model seems to underpredict full-time relative to RURO models, putting more weight into time regimes around 30hr/w and 70 hr/w. This could be a result of the discretisation of hours of work around these points.

Figure 2.1 Hours worked fit



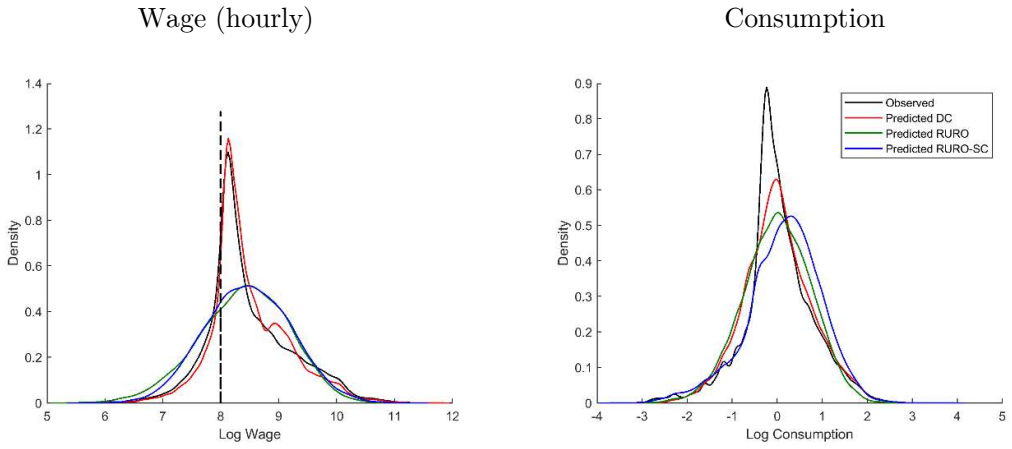
Source: Authors' calculations based on GEIH (2016)

[24] (Potential) experience is defined as age in years minus years of education minus 5 years.

[25] In this case, the group-specific formality rate varies for groups of gender, education, and region. Following Decoster, Capeau and Dekkers (2016), such a variable will help to identify the distinction between opportunities in both sectors.

Figure 2.2 presents wage and consumption (income) fit for the three models. As discussed before, in the DC model, most wages are not estimated but taken from the data. Discrepancies arise because wages are estimated for non-workers, therefore, the density shift to the right is a result of higher estimated wages for non-workers than observed wages for workers.

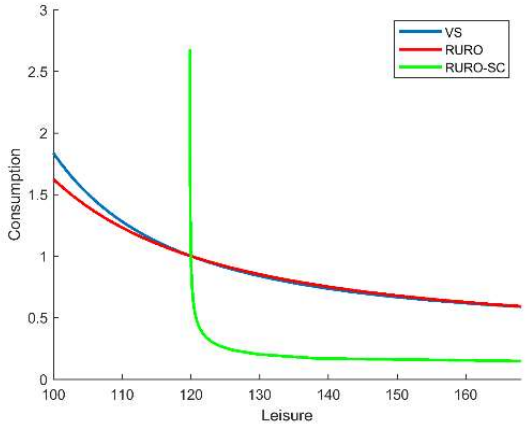
Figure 2.2 Wage and Consumption fit



Source: Authors' calculations based on GEIH (2016)

In the case of RURO, the first part of the distribution seems to be captured quite well. However, there is a higher dispersion of the predicted relative to actual data. This is a result of the bunching of wages around the minimum wage (represented by the vertical dotted line) which is not captured by RURO estimates. Consumption translates this wage feature, with the three models predicting more dispersed disposable income than the actual data.

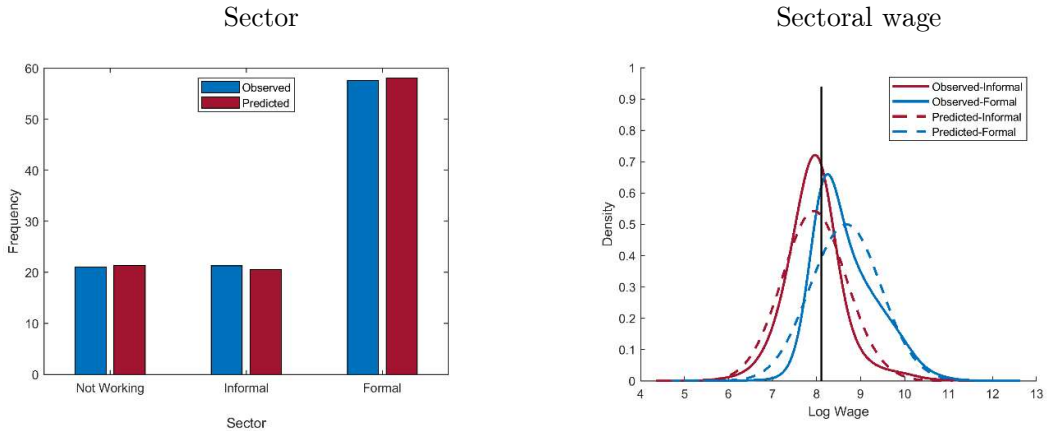
Figure 2.3 Indifference curves



Source: Authors' calculations based on GEIH (2016)

Indifference curves for the three models are presented in Figure 2.3. We fix utility at full-time (48hr/w) and one million Colombian pesos (around 1.45 times the monthly minimum wage in 2016). As expected from the estimated coefficients, the RURO model with sector choice displays a high degree of complementarity between leisure and consumption. However, omitting the differences between the two sectors provides more substitutability between them. The indifference curves in the former case greatly resemble those of a Leontief (minimum) function. Admittedly, the differences could be arising from a misspecification of the functional form of the utility function including a possible lack of utility differences for each sector. A further exploration of these issues is an important line of future research.

Figure 2.4 Sector and sectoral wage fit in RURO-SC



Source: Authors' calculations based on GEIH (2016)

Sector fit in the RURO model with sector choice

The sector fit of the more comprehensive version of the RURO model is presented in Figure 2.4. Despite the dramatical change in preferences for the RURO with sectoral choice, the extension of the model to capture formal and informal employment does a good job fitting the distribution between the two sectors and the non-working alternative. The model slightly overpredicts formal employment and underpredicts informal employment, but the differences with respect to actual data are negligible (around 1 percent). On the other hand, sectoral wage fit resembles the simpler RURO results: the model captures the mean but fails to capture the concentration of data, around the minimum wage (represented by the vertical line), especially for formal workers. This sectoral fit alongside the overall fit discussed previously and the sign of the coefficients in Table 2.2 gives

us some reassurance about the proposed model. Nevertheless, additional work is necessary to uncover the explanation behind the drastic change in preferences.

2.5 A simulation exercise

In this section we use the extended version of the RURO model to make three simulations that test the hypothesis of segmentation. We simulate exogenous variation of variables known to determine the likelihood of being formal. We hypothesise that if markets in developing countries are indeed segmented, the availability of job offers in the formal sector for workers that are currently in the informal sector (that the RURO model captures via the Poisson process in Equation 4) will change slightly. On the other hand, if workers are relatively free to move between sectors, a sufficiently high exogenous change will increase the attractiveness of formal employment and move a significant share of informal workers to the formal sector. Note that from the model's perspective the two alternatives could coexist, that is, for a group of workers the availability of alternatives could increase, while for the rest of them the availability could change little. Therefore, what we are trying to measure here is which alternative is more prominent in aggregate terms.

The first simulation (S1) assumes an increase in the level of education for all observed informal workers aged 18-40 to a tertiary education level. The simulation affects 13.3 percent of the sample and implies an increase in the share of informal workers with higher education from 14.5 percent to 67.5 percent and a reduction in the share of workers with primary education or less from 26.3 percent to 16.4 percent. As seen from the estimated coefficients in Table 2.2, such a change will reduce opportunities in the informal sector with an ambiguous effect on opportunities in the formal sector, given that both education coefficients are negative. The effect on wages is unambiguously positive, with wages increasing substantially more in the formal sector because both the penalty for having primary education or less, and the premium of higher education are higher. Overall, based on previous literature and on our parameter estimates, we expect the simulation to increase the attractiveness and availability of jobs in the formal sector relative to the informal sector.

In the second simulation (S2) we eliminate social insurance contributions for formal workers earning less than three monthly minimum wages. This simulation only operates via income and implies an 8 percent increase in labour earnings in the formal sector with the respective increase in disposable

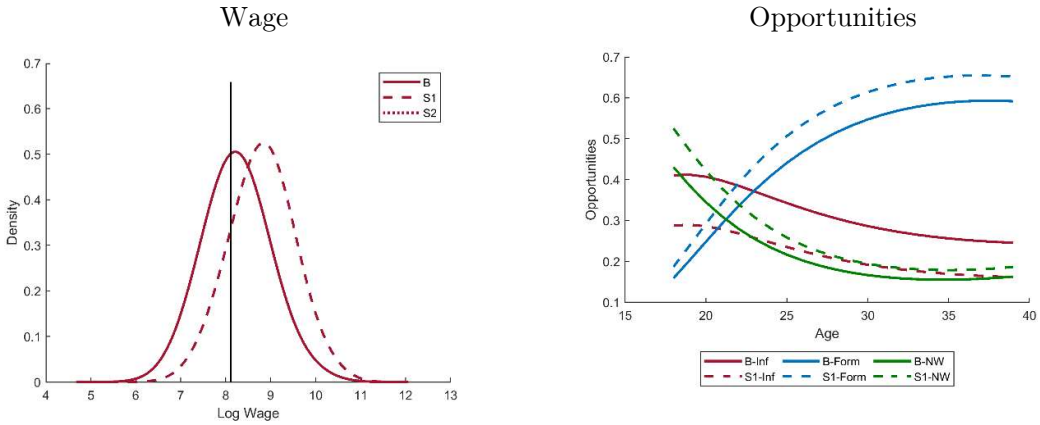
income for workers in this sector. Undoubtedly, this represents an increase in the attractiveness of jobs in the formal relative to the informal sector.

Notice that given the magnitude of changes in the two exercises proposed, the simulations will necessarily affect the job offer arrival rate; in other words, there are general equilibrium effects that we are not able to capture in the RURO model that could affect the results obtained.

2.5.1 Simulating changes on education and social insurance contributions

Figure 2.5 presents the change in simulated wages alongside the change in opportunities for informal workers aged 18-40 for the first two simulation exercises. For the graph in the right pane, opportunities are defined as the estimated probabilities $\pi_0, \pi_1, 1 - \pi_0 - \pi_1$. In the graph they are pictured for different age values and evaluated at the average of other covariates. The concave relationship between age and opportunities in the formal sector (captured by the red lines) is in line with previous Probit estimates for formality in Latin America such as Carneiro and Henley (2002) for Brazil or Cuevas et al., (2016) for Mexico. The availability of non-market opportunities (captured by the green lines) follows the pattern of a typical participation model: it decreases from age 18 onwards and increases at around 50 years old. As depicted with the dashed lines corresponding to the first counterfactual (S1), opportunities in the informal sector decrease by 10.7pp for informal workers. Correspondingly, their opportunities in the formal sector increase by 5.6 pp, with the difference (5.1pp) being an increase in the availability of non-market alternatives. Opportunities do not change for the second simulation by construction.

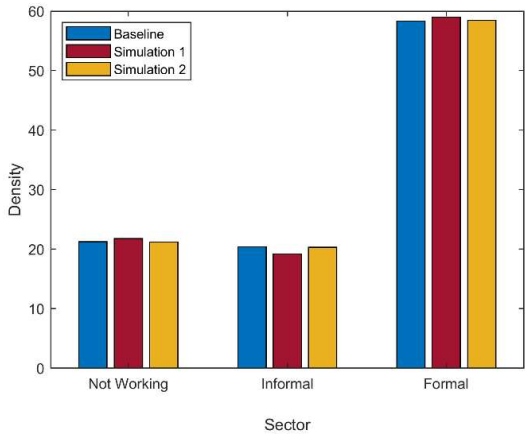
Figure 2.5 Simulated wage and opportunities changes



Source: Authors' calculations based on GEIH (2016) Note: Workers aged 18-40 years observed in the informal sector in the sample. Vertical line represents the minimum wage.

For the wage graph in the right pane of Figure 2.5, we first determine the best alternative among the 200 draws as detailed in section 2.3.5. Next, for the best alternative, we pick the corresponding hourly wage rate in the baseline (red line) and counterfactuals (dashed and dotted red lines). We observe that the average hourly wage for workers in the target group increases by around 68 percent, moving the wage distribution considerably above the minimum wage. Wages are not observed to change for the second simulation.

Figure 2.6 Sectoral Movement



		Simulation 1				Simulation 2		
		Not Working	Informal	Formal		Not Working	Informal	Formal
Baseline	Not Working	0.998	0.000	0.002	Not Working	0.996	0.000	0.004
	Informal	0.002	0.934	0.065	Informal	0.000	0.997	0.003
	Formal	0.009	0.003	0.988	Formal	0.000	0.000	1.000

Source: Authors' calculations based on GEIH (2016)

Despite considerable increases in education that in turn increase simulated wages in both sectors and job availability in the formal sector, there is a reduced movement of workers from the informal to the formal sector as seen in Figure 2.6. Only 6.5 percent of informal workers are observed making a transition between the two sectors. In the case of Simulation 2, only 0.3 percent of informal workers make a transition as a result of the increase by 8 percent of labour earnings for formal employees with low incomes. We observe that both simulations create incentives to work for those not working, resulting in some individuals moving from not working to working as formal. Lastly, hours worked do not change significantly for the two simulations relative to the baseline, average hours of work decrease 0.06 and 0 percent for the target group in each simulation, respectively. This effect could be a result of the reduced availability of time regimes at hours other than full-

time, 40 h/w or 60h/w but also due to the extreme complementarity estimated between leisure and consumption.

2.6 Conclusions

This paper proposed the study of labour informality with structural labour supply models estimated for a developing country such as Colombia. We presented an overview of the literature on structural labour supply and compared model fit and preferences for the most common models available for developed economies. As a motivating exercise for the scope of counterfactual simulations available with this type of models, we use our more comprehensive model and simulated exogenous changes in variables known to increase the likelihood of being in the formal sector: we increased education attainment, reduced worker social insurance contributions, and increased formal disposable income.

Overall, we find good model fit and the expected sign of most estimated coefficients. We find that preferences drastically change for different specifications of the labour supply models. Lastly, simulation of pro-formality policies results in a modest to null effect on the composition of the pool of workers between sectors, in line with the hypothesis of labour market segmentation. We argue that there are some unobserved factors that determine a great deal of formal job availability. Future research should explore which other variables not accounted for in our estimation contribute to enhancing formal opportunities for informal workers.

Although our modelling framework is built under some restrictive assumptions that future work should try to address, our results suggest, from a policy point of view, that governments should be more concerned about the determinants of opportunities in the formal sector such as education than about monetary incentives to formal employment. More importantly, education not only makes formal jobs more attractive from a monetary perspective (because it increases wages), but it also increases formal job availability for informal workers. In Colombia, as in many other Latin American countries, access to tertiary education has increased mostly as a result of higher household incomes. However, without substantive changes in education policies, only households which are already better off will be able to benefit from higher education and its earnings and opportunities premia in the formal sector.

We consider the labour supply framework presented in this paper as an important avenue for future research into informality. This is especially true given the lack of panel data for developing countries, but also the lack of a testable dynamic choice model of labour supply. Some advantages of our framework are the detailed treatment of individual budget sets; the inclusion of choice at the intensive and extensive margins; and the most detailed treatment of heterogeneity between workers which contrasts with the excessive number of behavioural assumptions in macroeconomic models. However, given the cross-sectional nature of the data and the restrictions on the sample, it is hard to generalise that the predicted movement between sectors of our model after exogenous changes will correspond to the reality of all informal workers, and our results should be taken with caution.

Some features worth improving for this framework are the inclusion of utility preferences over sectors, the inclusion of couples and the self-employed. While the first two have been previously considered in the literature (see Pradhan and van Soest, 1997), they require substantial additional computational efforts. In the case of self-employment, most labour supply models for developed countries omit them from estimation given the lack of reliable data on incomes, but also, because the incentive framework, including a wage might not seem appropriate in this case. Given that most informal workers are self-employed in countries such as Colombia, modelling their labour market choice would represent an interesting and important line of research.

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A.2 Appendix

Table A2.1 Wage and participation estimation for DC model

Variable	Probit (first stage)	OLS (second stage)
Age	0.086***	0.018***
	(9.27)	(4.63)
Age2	-0.001***	-0.000*
	(-9.9)	(-1.67)
Higher education	0.316***	0.652***
	(9.99)	(54.03)
Lower education	-0.309***	-0.446***
	(-7.35)	(-23.54)
Bogota	0.561***	0.136***
	(8.31)	(6.64)
Male	0.089**	0.148***
	(2.51)	(12.52)
Other Earnings	-0.143***	
	(-51.55)	
Property	-0.157***	
	(-4.28)	
Child 0-2y	-0.235***	
	(-4.58)	
Child 3-4y	0.096*	
	(1.69)	
Child 5-10y	0.127***	
	(3.44)	
Child 11-18y	0.221***	
	(6.19)	
inverse Mills-Ratio		-0.012
		(-0.58)
Constant	0.391**	7.640***
	2.29	104.97
Observations	15,347	12,111
Adjusted or pseudo R-squared	0.329182	0.308396

Source: Authors' calculations based on GEIH (2016)

Chapter 3: The role of job contact networks on formal-informal labour dynamics[1]

Abstract

This paper explores the potential use of agent-based models in the informality literature, and to do so it uses this methodology to study the effect of contact networks as a job-search mechanism on an economy with a substantial informal sector. We extend a model capable of replicating a large number of stylised facts from the macroeconomics literature to incorporate firm heterogeneity, and more importantly, the endogenous formation and use of job contact networks. Given that model intractability has resulted in few networks studies, the proposed framework allows us to disentangle the effect of networks, especially in the presence of a large share of small firms as in most developing economies with an informal sector. Estimating most of the technology and job-search parameters of our model using Colombian household data, we find a high degree of sectoral homophily in contact networks: informal and formal workers have on average 70.3 and 81.5 percent of connections in their sectors, respectively. However, the current propensities of direct and indirect (that is, with contacts) search do not prevent workers from changing sectors and, only under extremely high propensities of indirect search do we notice effects on the real variables of the economy and on the formality-informality divide. Based on our exploratory analysis, we argue that the proposed framework could complement traditional macroeconomic models of informality, especially when modelling complex phenomena.

JEL: E26, C63, C69

Keywords: Job contact networks, informality, agent-based models, computable macroeconomics

[1] I would like to thank Simone Giansante for introducing me to the Lengnick (2013) model and the JAS software. I extend my thanks to Matthias Lengnick for valuable advice on the baseline model. Also, to Ross Richardson and Matteo Richiardi for useful suggestions on the use of the JAS-mine software. All remaining shortcomings are my responsibility alone.

3.1 Introduction

Given the contrasting differences in labour market outcomes between developing and developed countries, there is still a great need for analysis and policy recommendations on the ongoing failure to expand formal employment in the first group of countries. Informal labour markets are usually deemed as segmented, and therefore, models incorporating the demand for labour alongside the availability of information on job openings are the most appealing for this task. Literature on informality from a macroeconomic perspective has focused on general equilibrium models in dual-market (formal and informal) economies, in which, a representative agent (worker and/or firm) chooses between sectors based on the comparison of expected utilities. Counterfactual experiments allow the researcher to analyse how exogenous variables such as the minimum wage, preferences or other policies affect the size of informal activities, but also, whether reforms that decrease informality improve welfare. Ideally, these insights would translate into policy recommendations.

Building on the seminal works on equilibrium in dual-market economies of Rauch (1991) and Loayza (1996), we find the more elaborated models of Straub (2005), Amaral and Quintin (2006) or Loayza and Rigolini (2011) which introduced among others: the effects of payroll taxes, and firm and worker heterogeneity. More recently, literature on informality has moved this equilibrium framework to the search and matching approach pioneered by Diamond (1982) and Mortensen and Pissarides (1999). In this line, we find the works of Zenou (2008), Satchi, and Temple (2009), Albrecht et al., (2009), Bosh and Maloney (2010) and Bosch and Esteban-Pretel (2012) introducing search frictions, endogenous job destruction and wage bargaining, among others.

One unexplored topic in the informality literature is the role of job contact networks in the job search. This could be the case because networks are intractable objects in an already mathematically complicated general equilibrium problem, to the point that most theoretical job network studies resort to numerical simulation given the impossibility of obtaining analytical expressions for employment in the presence of even simple network structures (Krauth, 2004, Calvó-Armengol and Jackson, 2004, Arrow and Borzekowski, 2004). The lack of economics literature on job contact networks in general is pervasive, despite networks being important sources of job information. To put things into perspective, according to data from the Statistics Office, in Colombia, half of employees obtained their job through friends, colleagues and relatives, and 2/5 of the unemployed are

looking for a job using contacts.[2] Similar magnitudes but higher heterogeneity in the use of contact networks have been observed for very different economies such as the US and Europe but also within different socioeconomic groups (Ioannides and Datcher, 2004, Pellizzari, 2010). Moreover, the effect of job contact networks on employment inequalities is a contested topic. Although networks reduce asymmetries of information, increasing overall employment rates, wages, and the quality of worker-employer matches (Bayer et al., 2008, Caliendo et al., 2011, Brown et al., 2016); it is also known that network homophily decreases the quality of employment outcomes for disadvantaged groups (Battu et al., 2011; Holzer, 1987; Calvó-Armengol and Jackson; 2004, Krauth, 2004).

The overall objective of this paper is to explore how agent-based models (ABMs) could be introduced in the informality literature and to highlight the advantages of this methodology, especially to model complex phenomena where mathematical solutions are not easily available. Moreover, our paper seeks to contribute to the limited, but growing, literature on networks in labour economics by studying the endogenous formation of job contacts on the job. Such a mechanism could potentially lead to a higher segmentation of labour markets in developing economies as information on job openings in the formal sector could not reach the informal sector. We develop a model of an economy consisting of households offering homogenous labour and firms with heterogeneous productivities producing a single consumption commodity in the spirit of Lucas (1978). However, we depart from traditional equilibrium models to overcome the problems of introducing contact networks. In our economy, production, work, and consumption decisions are based entirely on local knowledge and heuristics and therefore, there is not an a priori market-clearing mechanism. Our macroeconomic model is an extension of the ABM of Lengnick (2013) that additionally considers formal and informal activities, differences in firm size between these sectors and introduces the formation of job contacts on the job as a novel feature. We build from an existing ABM instead of starting a model from scratch for three reasons: to capture general equilibrium effects, to contribute to dissemination of the simple framework proposed by Lengnick (2013), and to allow for comparability between our model and the recent informality literature that has a macroeconomic perspective.

[2] Data sources are presented in detail in section 3.3.1.

To better motivate the use of ABM and particularly the Lengnick (2013) model in the informality literature we present a detailed overview of our modified version of the model. We also discuss at length the introduction of job contact networks and their potential effect on labour market segmentation. We estimate most of the technology and job-search parameters of the model for the Colombian economy and take other parameters from the original Lengnick work, especially those concerning the demand for the consumption commodity. Our exploratory model indicates that job contact networks display a high degree of sectoral homophily, however, the current propensities of direct and indirect search do not prevent workers from changing sectors. We observe workers visiting formal and informal firms regardless of initial job conditions and network size. Moreover, we find that, controlling for firm size and number of job contacts, a 10pp increase in the propensity of use of contact networks increases the probability of making a sectoral transition by 9.1 percent. This positive effect is, nonetheless, marginally decreasing because of congestion in the use of networks.

In the following, Section 3.2 revises the most important features of macroeconomics models of informal markets, previous studies on the role of job contact networks and introduces ABMs. Section 3.3 presents some stylised facts of informality in Colombia. Section 3.4 discusses the model in detail. Section 3.5 presents some counterfactual exercises. The sixth and last section presents conclusions.

3.2 Informality, labour dynamics and job contact networks

In this section, we review some models on labour dynamics in the presence of informality, we explore how job contact networks are accounted for in labour economics and lastly, we introduce ABMs, especially as applied to labour economics. We argue that ABMs are an important tool that complements traditional equilibrium models and increases our understanding of labour dynamics, especially when dealing with mathematically intractable structures such as networks.

3.2.1 Equilibrium models of informality

Most of the research on labour informality at the macro level has a two-sector equilibrium perspective. The pioneering work of Rauch (1991) proposes a theoretical model with a continuum of agents endowed with different levels of "managerial talent" that allow them to create a firm and hire

workers. Depending on a simple comparison between wage as an employee with earnings as an entrepreneur, agents choose one or the other role. After the introduction of a minimum wage enforced only for big firms, a continuum of firms paying wages below the minimum (informality) appears. In the same spirit, Loayza (1996) develops a growth model in which agents transform an endowment of capital into output and decide whether to be formal, which implies paying taxes and benefiting fully from a positive externality of public goods, or to be informal and pay a penalty proportional to output, receiving only a reduced effect of the externality. Equilibrium is determined when returns in both sectors are equal. He concludes that institutions and policies that increase the informal sector size will reduce growth.

More recently, Ulyssea (2018) studies informality with a general equilibrium model encompassing the extensive (that is, firms decide whether being formal or not) and intensive (firms decide the combination of informal/formal workers to hire) margins of informality. To account for the intensive margin, he assumes that labour costs are a marginally increasing function of the number of informal workers, but a linear function of the number of formal workers (with the slope given by the payroll tax). The nature of the costs functions implies that formal firms first hire workers informally up to a threshold over which every additional worker is hired formally. The introduction of such a convex cost function for informal hiring, with no theoretical basis, is a recurrent feature of this strand of the literature. Lastly, potential entrant firms decide the sector, or no entry, based on a noisily productivity signal that is fully revealed ex-post, allowing for the overlapping of productivities between formal and informal firms observed in the data.

Recent research on informality builds on this equilibrium framework but introduces market frictions following the search and matching approach pioneered by Diamond (1982) and Mortensen and Pissarides (1999). The seminal work of Zenou (2008) proposes a model comprising identical firms and workers within formal and informal sectors. A matching function determines the meeting process between unemployment and formal vacancies.[3] The informal sector does not display such a queue process but works as a competitive market; therefore, if workers decide to work in the informal sector, they find a job instantaneously with a wage equal to the marginal product of labour.

[3] Informal workers must stay unemployed for one period to queue for a formal job. Moreover, formal workers will not look for informal jobs, preferring to remain unemployed.

Firms enter the formal market until the value of a filled job is equal to search costs, with wages determined following a Nash bargaining process. After calibrating the model to a hypothetical economy, some policy simulations show that reducing unemployment benefits, subsidising firms' entry costs or imposing wage subsidies will decrease the size of the informal sector.

In the same vein, Albrecht et al., (2009) assume workers with heterogeneous productivities and endogenous job destruction.[4] They find that increasing payroll taxes and severance payments increases the size of the informal sector at the expense of workers in the formal sector. The effect of these variables on unemployment is opposing, higher severance payments reduce unemployment because they increase employment duration in the formal sector while higher payroll taxes increase unemployment.

Lastly, Meghir et al., (2015) extended the Burdett and Mortensen (1998) model of wage differentials to an informal economy populated by homogenous workers and productivity heterogeneous firms deciding to post jobs in the informal or formal sector. The model is estimated for groups of unskilled males and females in the Sao Paulo and Salvador regions in Brazil. In a counterfactual exercise, it is found that increasing the cost of operating in the informal sector (firm enforcement) increases welfare by moving workers to higher productivity jobs.

Despite the importance of job contact networks and the growing study of them for developed economies, their analysis in informality models is, to our knowledge, non-existent. We now turn to the literature on networks, mostly for developed countries, and their effects on labour market outcomes.

3.2.2 Job contact networks and labour markets

The role of contact networks for job search has been studied extensively by sociologists, while economists' understanding of them is much less developed (Ioannides and Datcher, 2004). Three recurrent topics have caught most of attention in our profession: link strength, network structure and formation, and the use of contact network for referral job application. Although the literature suggests that the use of contacts improves the quality of outcomes, it also highlights that disadvantaged groups could be better off attempting a direct job search because network homophily,

[4] Separation is of mutual interest for firm and worker.

that is, the tendency of individuals to have ties with others similar to themselves, could prevent them from receiving information on better paid job openings. These contrasting results have not yet been analysed for another disadvantaged group of workers such as the informal in developing economies.

In an early analysis of link strength, Granovetter (1973, 1983) classified links as strong (close friends) or weak (acquaintances), establishing that social systems without weak ties are fragmented as individuals are "deprived of information from distant parts of the system" (Granovetter, 1983, p. 202). In this sense, information regarding job openings from close friends usually overlaps with the information an individual already has, but as acquaintances move in different circles, they have better access to new information. Empirical literature on the strength of the weak ties assertion has delivered mixed results, especially given the lack of data and problems measuring link strength (Aral, S. 2016).

Two interesting findings are provided by Battu et al., (2011) analysing job search methods for minorities in the UK. First, foreign-born ethnic groups initially rely heavily on strong ties relative to direct job search, possibly as a result of gradual assimilation. However, in the long-run they tend to use direct search methods as much as native-born populations. Second, controlling for job search mechanisms, minorities are less likely to find a job, or in the case of finding one, the position is of inferior quality than that for similar native-born workers. The authors consider that minorities in the UK have poor quality personal networks or that they use them inefficiently.

Regarding network formation and structure, Calvó-Armengol (2004) and Calvó-Armengol and Jackson (2004) study job information flows in games of strategic contact network formation, where keeping contacts is costly. Their models establish the existence of equilibrium and the prevalence of worst outcomes for groups initially in worst-employment status. Using a similar methodology, Galeotti and Merlino (2014) found that there is a U-shaped relationship between investment in job contacts and the separation rate: workers do not expand their connections if a) there are very low separations, because it is less likely they lose their job; b) there are high separations, because it is more likely others are also looking for a job. The authors also found this relationship empirically for the UK.

Literature on referral hiring highlights that firms approximate an applicant's productivity with that of an employee referring him. This could be a result of perceived network homophily. Brown et al., (2016) use firm-level data to test some hypotheses for referral hiring. They found that referred workers are more likely to be hired than non-referred, to have higher initial wages and longer tenure, but that most differences decrease over time. Krauth (2004) proposes a dynamic setup in which firms discover potential workers' productivity by exogenous referral networks. Using different network structures and sometimes resorting to simulations, his model supports Granovetter's (1973) weak ties assertion but also, that social isolation leads to high unemployment for disadvantaged groups. Pellizzari (2010) uses panel data from Europe and the US to show that there are wage premiums and penalties of using job contact networks, where penalties could be the result of mismatches between firms and workers. Lastly, Arrow and Borzekowski (2004) explore the effects of networks on earnings differentials through a model in which firms bid for homogenous workers in a second-price auction. Firms base their offered wage either on a productivity signal in the case of a referral, or a "common knowledge" ability level in the case where there is no such connection. Calibrating the model to the US distribution of wages, they found that around 1/6 of wage variance could be explained by networks.

From the ABM literature, Tassier and Menczer (2001) study contact networks in an evolutionary labour market in which individuals search for jobs directly or through contact networks, both alternatives being costly. Wages and layoffs are random, and agents die or multiply depending on the fitness of the individual effort placed on each strategy for obtaining jobs, which in turn changes at random, guaranteeing that only the best strategies and networks structures are used by the remaining agents in the long-run. They find that agents create many more links than is socially desirable.[5] Additionally, Gemkow and Neugart (2011) propose an ABM of referral networks in which agents adjust their costly network size depending on the payoffs obtained. Similarly to Galeotti and Merlino (2014), they find that network size decreases when labour market volatility increases, because keeping friends is expensive if they are also searching for jobs themselves. Below, we turn to a more in-depth analysis of ABM in the labour economics literature.

[5] That is, more links than those that maximise population size.

3.2.3 Agent-based model in labour economics

In a typical ABM, a large number of agents are introduced into a simulation environment. Each agent is characterised by a set of simple rules of behaviour of the "if-then" type, including interaction with other agents that could potentially alter their state variables. It also incorporates randomness via Monte Carlo methods. At the first simulation time-step, agents are called to perform their predefined rules based on initial values for their control variables. At the end of the first time-step, the state of the simulated economy could be analysed at the micro (that is, agent) level or at the macro level (by aggregating agents' results). The second time-step of the simulation starts based on the first-step results for control variables and so on. Most of the time, the researcher is interested in the long-run effects of changes in the parameters governing the rules of behaviour, but also in the long-run properties of the model, the most important being ergodicity, a condition under which a model with the same parameter values will always converge to the same statistical equilibria, that is, regardless of the initial conditions of control variables the model will exhibit a similar long-run behaviour. If a model is ergodic, a time series derived from one model run gives information for estimating the underlying laws of motion of the ABM (Delli Gatti et al., 2010, Grazzini and Richiardi, 2015, Grazzini, Richiardi and Sella, 2018).

An ABM has several advantages over traditional economics models. Firstly, it overcomes "representative agent" restrictions by allowing individual heterogeneity for a large number of agents. Dynamics do not require rational expectations or extreme rationality assumptions for model tractability; instead, simple heuristic rules based on local knowledge result in "emergence" of observed phenomena at the macro level.[6] [7] Market equilibrium is not imposed ex-ante but is achieved by the interaction of different types of agents with opposing interests, for instance, households and firms. On the other hand, ABMs have some important weaknesses. Model flexibility usually goes hand in hand with excessive freedom, and proliferation of models, which are usually tailored only to the problem at hand (Turrel, 2016). Moreover, while an ABM requires substantive computational

[6] With rational expectations we refer to the assumption that all individuals in the model have unlimited computational ability and are fully informed about the structure of the model. Moreover, all agents know that other agents possess the same knowledge. This assumption usually implies that individuals make no systematic errors in their choices.

[7] Emergence could be defined as unintended and unplanned aggregate outcomes from the model resulting from individual human actions and dispersed interactions (Delli Gatti et al., 2010).

skills, its code is rarely reused, which has prevented a more rapid take-off of the methodology (Leombruni and Richiardi, 2005).

In the case of the labour market ABMs, there have been two main approaches (Neugart and Richiardi, 2018): the first simulates the labour market only, similar to partial equilibrium analysis (Richiardi, 2006, Neugart, 2008, Boudreau, 2010, and Ballot and Taymaz, 2001); the second incorporates the labour market into a macroeconomic model (Gaffeo et al., 2008, Russo et al., 2007, Lengnick, 2013, and Dawid et al., 2016).

Richiardi (2006) proposes a labour market model in which agents with different productivities and preferences decide between working as employees, employers and not working. They compare the average wage in the economy with the payoff of starting a new business, which in turn depends on the average productivity and the prospective number of workers. The costs of the start-up are wages, which are an idiosyncratic share over the productivity of workers, and a fixed cost of posting vacancies. If agents decide to be employees, they randomly ask firms for open positions, while each firm keeps the most productive applicants. The model reproduces some of the macroeconomics stylised facts: Beveridge, Okun and wage curves, but only finds support for a negatively sloped wage curve and a constant returns to scale matching function when the model is "out of equilibrium".[8]

Neugart (2008) evaluates the effects of government-financed active labour market policies in a market with different sectors. After a sectoral negative shock, all workers become unemployed and must acquire job-specific skills to apply for jobs in similar sectors. Governments could provide training, which is financed by taxing the employed. It is found that government intervention reduces the unemployment rate by increasing the outflows from unemployment to employment for those receiving the training subsidy, but it reduces the outflows of those not receiving it.

Turning to labour market modules embedded in macroeconomic models, Gaffeo et al., (2008) propose a model with firms, households and banks in which productivity is raised by investment in R&D.[9] Workers supply one unit of labour each period. They apply to a list of firms including their current employer and accept the one offering the highest wage. Wages are individually tailored and

[8] This is, after the model has received an exogenous shock and re-accommodates towards equilibrium again.
[9] Based on the same model as Russo et al., (2007).

cannot go below a minimum wage (established by law), updated for inflation each period. The model replicates most macroeconomics stylised facts for developed economies including the co-movements of aggregate variables with output usually observed.

Lastly, the EURACE model (Dawid et al., 2016) presents a very detailed ABM of the European economy with hundreds of millions of interacting agents of three types: households, firms, and banks. The model includes five markets: consumption and investment goods, labour, credit, and financial assets, with most of them working at the local level, that is, each one of the 268 NUTS-2 regions in the EU. The model's labour market module comprises a search and matching algorithm in which firms post vacancies for different skill levels. Unemployed households and a fraction of employed households (on-the-job search) look for jobs and apply to those firms offering a wage above their reservation wage. Firms rank applications by skill level and send job offers that are considered by households. If firms do not fill their positions or households remain unemployed, they adjust the wage and the reservation wage, respectively. The model has been used among others by Dawid et al., (2012) to study the integration process of Eastern European labour markets to the European Union, where it is found that the highest output gains come from opening the labour markets, but at the cost of increasing regional disparities in economic outcomes.

3.3 Informality: some motivating facts for Colombia

3.3.1 Data

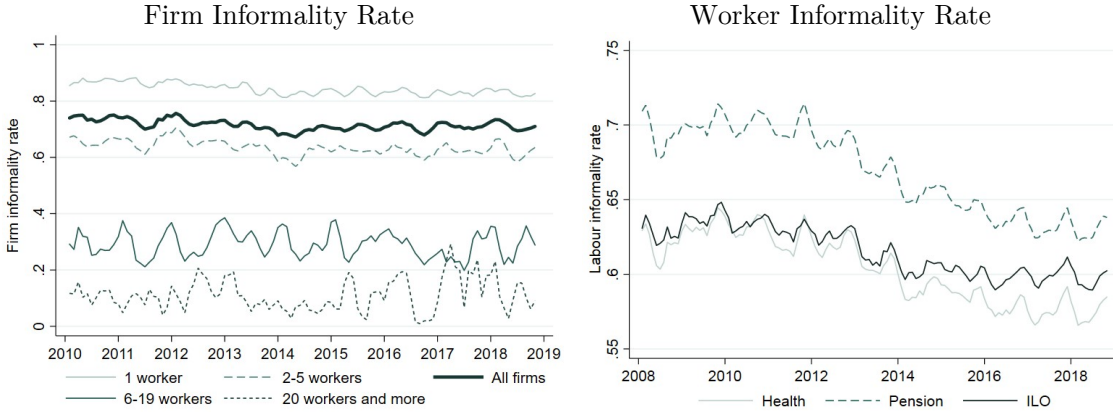
Throughout the remainder of the paper we use information from two household surveys representative of the entire Colombian population: 1) the Great Integrated Household Survey (Gran Encuesta Integrada de Hogares, GEIH), a cross-sectional labour force survey with a monthly sample size of around 28,000 workers, from which we use information spanning a nine-year period (2010-2018); 2) The Social Protection Panel Study (Encuesta Longitudinal de Protection Social, ELPS), a household survey for 2012 with work history information for 41,049 working-age individuals.

3.3.2 Stylised facts

Informality has been a pervasive feature of the Colombian economy and more importantly, a known determinant of low tax revenues and low social security coverage in the country. Despite the lack of consensus on its definition, informality is high in the country by any measure. Figure 3.1 presents

firm and worker informality rates for recent years, with firm formality defined in terms of a firm's registration and worker formality defined in terms of workers' contribution to health insurance, to a pension fund (legalistic view) or alternatively the official ILO definition comprising workers in firms with more than five employees.[10]

Figure 3.1 Firm and worker informality rates in Colombia.



Source: Authors' own calculations based on GEIH 2008-2018, Quarterly Moving Averages. For the firm informality rate we divide firms by size in workers. For the worker informality rate, Health(pension) measures the proportion of workers not contributing to Health Insurance (Pension). ILO: measures the proportion of workers in firms with five employees or less.

The share of informal workers in Colombia declined by around 5 percentage points from 2008 to 2014 but has been relatively stable at values ranging from 60 to 65 percent since then. On the other hand, firm informality has been relatively constant over time, and as expected, is higher for smaller firms: above 80 percent for firms with one worker (which account to nearly 40 percent of total firms) and around 70 percent for firms with 2-5 workers. It is still positive but low for large firms: around 10 percent for firms with 20 workers or more.

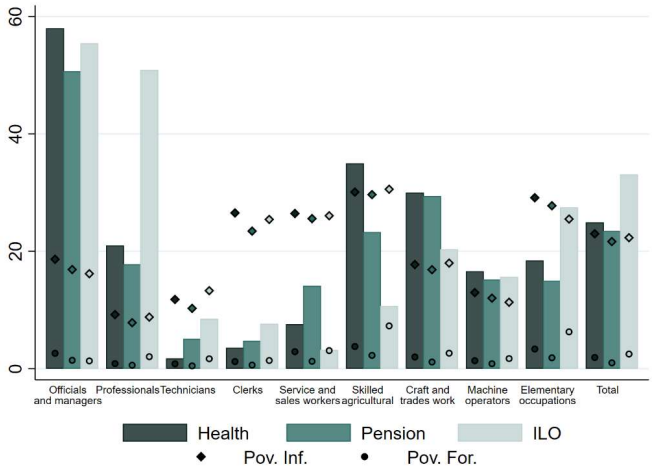
Another important feature of informality is earnings precariousness. Informal employment is usually observed at the bottom of the earnings distribution with formal employment usually better remunerated even after controlling for individual and job characteristics. In Figure 3.2 the earnings gap resulting from an Oaxaca decomposition for each occupation is depicted alongside the share of workers with monthly earnings below the poverty line in each sector.[11] The earnings gap, despite being heterogeneous across occupations, is always positive, ranging from 2 percent for technicians

[10] Professional self-employed workers are also considered formal by ILO.

[11] The decomposition uses a Mincer estimate of log hourly earnings on age, age squared, gender, education, industry, region, urban and year dummies. The decomposition is applied for workers in each occupation depicted in the horizontal axis of Figure 3.2.

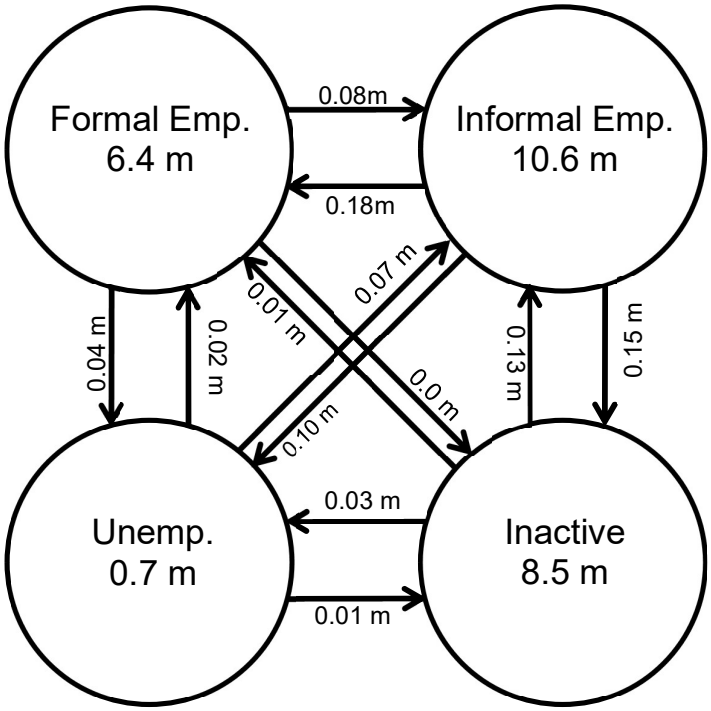
to 58 percent for managers. Correspondingly, the share of workers with extremely low incomes is higher in the informal sector (around 22 percent with incomes below the national poverty line) than in the formal sector (less than 4 percent).

Figure 3.2 Earnings gap and poverty incidence by occupation



Source: Authors' own calculations based on GEIH 2008-2018, monthly earnings include: employee wages and bonuses and self-employment net profits.

Figure 3.3 Worker stocks and flows in the Colombian Labour Market in millions



Source: Authors' own calculations based on ELPS 2012, transitions at quarterly level.[12]

[12] Transitions correspond to September relative to June 2012 for working-age individuals aged 18-60.

This informal-formal earnings gap is the workhorse of economists arguing that there are important barriers preventing informal workers from formalizing. However, recent research partially dismisses this conclusion, pointing out that there are significant worker flows between the two sectors and that their coexistence can be thought of as the natural result of workers benefiting from comparative advantages in each one (Maloney, 1999). As depicted in Figure 3.3, each quarter 1.7 percent of informal workers move into the formal sector in Colombia and 1.3 percent of formal workers enter informality. These figures are much lower than in countries such as Mexico: 24.4 and 7.8 percent respectively (del Angel, 2013) and Argentina: 9 and 4.2 percent respectively (Albertini et al., 2019), possibly an indication of segmentation of the two sectors in Colombia.

How does the use of job contact networks affect the depicted worker flows and employment outcomes? To partially address this question, Table 3.1 presents three linear probability models, and one earnings estimate as functions of personal and job characteristics, all involving the degree of use of contacts for job search. More specifically, the first and last models capture the determinants of the probability of finding a job using contact networks for those previously employed or of searching for a job with contact networks while unemployed, respectively. The second and third model estimate the effect of personal characteristics, including whether contact networks were used to obtain the current job, on the probability of being informal and on log-earnings, respectively.

From models 1 and 4, high values for intercepts indicate that the probability of using or obtaining a job through contact networks for unemployed and employees respectively is high. Additionally, the proportion of jobs obtained using contacts is higher than the frequency of use for those unemployed, indicating a high degree of efficiency of contacts in getting jobs. Moreover, males resort the most to contacts, while the effect of age on their use is not clear. Lastly, education is strongly negatively correlated with the use of contact networks: having higher education is associated with a decrease of around 26 percentage points in the probability of obtaining a job (or searching for a job) through contacts for those employed (unemployed).

From models 2 and 3, it is also clear that obtaining a job using contacts implies worse employment outcomes: a higher probability of the job being informal and lower earnings. Despite this suggestive evidence of the negative effects of resorting to contact networks on employment outcomes, our

estimates do not take into account the potential sorting of workers into using job contact networks and therefore, the interpretation of these coefficients could be misleading.

Table 3.1 Job contact network use, informality, and earnings

		Employment			Unemployment
		(1)	(2)	(3)	(4)
	Dependent Variable	Job Networks	Informality	Log-Earnings	Job Networks
	Age [18-30]	0.005***	0.126***	-0.145***	-0.198***
		(3.3)	(100.81)	(-67.07)	(-73.37)
	Age (30-50]	-0.017***	-0.010***	-0.063***	-0.131***
		(-12.29)	(-7.78)	(-32.34)	(-46.93)
	Male	0.009***	-0.036***	0.013***	0.061***
		(9.72)	(-46.73)	(9.89)	(40.24)
	Skilled	-0.263***	-0.216***	0.357***	-0.279***
		(-297.01)	(-264.59)	(238.73)	(-177.86)
	Informal			-0.183***	
				(-124.53)	
	Job Networks		0.276***	-0.043***	
			(338.46)	(-33.12)	
	Constant	0.853***	0.137***	7.703***	0.641***
		(371.43)	(63.51)	(262.88)	(147.57)
Dummies	Region	YES	YES	YES	YES
	Time	YES	YES	YES	YES
	Occupation	NO	NO	YES	NO
	Industry	NO	NO	YES	NO
	Observations (Millions)	1.19	1.19	1.19	0.375
	Adj. R-squared	0.093	0.208	0.462	0.133

Source: Authors' own calculations based on GEIH 2010-2018, t statistics in parentheses, significance level: *** p<0.01

Even if these estimates are correct, there are important questions that could not be answered within this simple framework. In the absence of comprehensive information on the networks of friends and colleagues for job search, in Section 3.4 we turn to a more elaborated model that tries to capture most of these informality facts to disentangle the real effects of the use of job contact networks. We turn to a macroeconomic model because, as we will see, most networks studies have neglected the effects of firm size on network formation, but this feature seems important in economies with large informal sectors characterised by an over-abundance of small firms, where the possibility of making job contacts on the job is greatly reduced.

3.4 Methodology

From section 3.2, it is clear that ABMs capture most of the features of the search and matching literature used in recent research on labour informality. Moreover, the time-step nature of ABMs allows for the incorporation of networks, in stark contrast to mathematically-driven models. The

model we propose next follows the macroeconomic perspective discussed for ABMs but encompasses firm-household and household-household networks of agents, with households taking advantage of their job contacts to discover better labour opportunities. In this regard, firm size pays a crucial role in the formation of contact networks and consequently, special efforts are taken to properly capture this feature in the Colombian economy we simulate.

Our macroeconomic model is an extension of the macroeconomic ABM of Lengnick (2013) that additionally considers formal and informal activities and differences in firm size between these sectors. There are several reasons for modifying an existing macroeconomic ABM instead of creating a "partial equilibrium" ABM from scratch. First, the model allows us to include the feedback of the goods market (general equilibrium effects) especially considering that when firms adjust output/inventories after changes in demand they necessarily readjust their payrolls. In a "partial equilibrium" model we would have to exogenously assume a stochastic process of job creation and destruction. Second, as discussed, an important problem in the ABM literature in economics is the lack of model recycling. Given that the Lengnick (2013) model is relatively simple yet comprehensive, its description and the release of the implementation code could allow the creation of different extensions in future research, whether in the informality literature or other macroeconomic simulations. Third, as previously discussed, the current literature on informality consists mainly of general equilibrium models and, therefore, a partial equilibrium will be more difficult to compare against those models and also more prone to criticism.

3.4.1 The model

The macroeconomic ABM developed by Lengnick (2013) features a two-market exchange economy in which firms produce a single physical commodity using homogenous labour as input.[13] In our version of this model, firms are labelled formal or informal, with differences between the two types in terms of productivities only. Households are single-member and offer one unit of labour per day inelastically to firms in exchange for a wage that allows them to buy the physical commodity. Given the agent-based nature of the model, knowledge for firms and households is local, that is,

[13] We restrict the model to homogenous labour because of the lack of firm data to derive production functions using different types of labour. However, considering that the Colombian economy has important differences in educational attainment, including skilled and unskilled labour, this seems like an important avenue of future research.

they only relate to a small network of agents from which they obtain information about current prices or jobs. It is assumed that there are a fixed number of firms n_f and households n_{hh} living for the entire simulation period and that agents are endowed with liquidity to trade with each other. For simplicity, no exogenous growth of technology is assumed.

The model defines a day as the basic time unit, with 21 days as a month. From a time perspective, there are three important events in a month: on the first day, each firm and household plans activities, decides prices, consumption, and changes connections to better exchange partners (that is, labour market and good market connections) depending on results from previous periods. Households also search for jobs, potentially using their contact network in the process. Throughout the entire month, each firm produces with its current number of workers, and households buy the single commodity using their available liquidity. On the last day of the month, each firm pays wages and profits to households. And lastly, households adjust the reservation wage depending on their labour status and update their job network.

It is also assumed that, at any time, each household has three types of connections: the first type (Type A connection) consists of links with seven different firms for buying consumption goods; the second type (Type B connection) consists of one link to a firm to supply labour in exchange of a wage[14]; the last type (Type F connection) consists of connections between households with up to ten job contacts. Firms are not limited in the number of goods or labour market connections possible, but given that their number is fixed, which precludes firm creation and destruction, it is assumed that the minimum number of workers a firm has is equal to one. No interaction between any two firms is assumed. Stochasticity enters the model via Monte Carlo methods in three ways: agent's rules are performed conditional on random draws; the adjustment rates of prices in the model are drawn from uniform densities; and agents are taken randomly to perform some action, for instance buying goods, changing their job network or searching for jobs. A detailed description of the rules governing the model is presented below, while Figure 3.4 presents a summary of them from a time perspective.

[14] The properties of the model under different Type A and Type B network sizes are explored at length in Lengnick (2013). It is shown that the results of the model only change for very extreme network scenarios.

We keep the model simple and abstract from government intervention, neglecting the role of minimum wages, income, and payroll taxes, and also those fringe benefits associated with a formal job. More importantly, we also assume that only workers change between sectors, not firms. Despite being typical in similar informality studies, we consider the omitted features to be of less importance, our focus being on the effects of using contacts for job search on the formal-informal divide for workers.[15]

Preliminaries and Timing

When introducing firm heterogeneity, previous literature assumes a continuum of firms and workers, with productivities drawn from probability density functions following the seminal paper of Lucas (1978). This approach is usually applied to make models mathematically tractable. When the model is applied to the data, these densities are assumed with as few parameters as possible while mimicking the features of the productivity distribution of the economy they represent. For instance, Ulyssea (2018) assumes that pre-entry productivity is governed by a Pareto density, while post-entry productivities are distributed as Pareto-Log Normal; Meghir et al., (2015) assume a log-normal productivity distribution. The three and two parameters governing technologies in each paper respectively are estimated using Brazilian data.

Given that firms and workers in our model are finite objects taking decisions based on their current individual statuses, we depart from continuous densities and consider productivities as discrete random variables with conditional probabilities over size (in workers) and sector (that is, whether the firm is formal or not):

$$\begin{gathered} P\left(tfp = tfp_{sector,size}\right) = P_{sector,size} \\ sector = \{informal, formal\} \quad size = \{size_1, size_{2-3}, size_{4-5}, size_{6-1}\ , size_{11-}\} \\ \sum_{sector,size} P_{sector,size} = 1 \end{gathered} \tag{1}$$

where $tfp_{i,j}$ is the total factor productivity of a firm of size j in sector i., $size_j$ stands for firms with number of workers in the interval j. Naturally, each firm's size is endogenous to the model, therefore, the estimation will recover the values of each of the parameters $tfp_{sector,size}$ such that long-

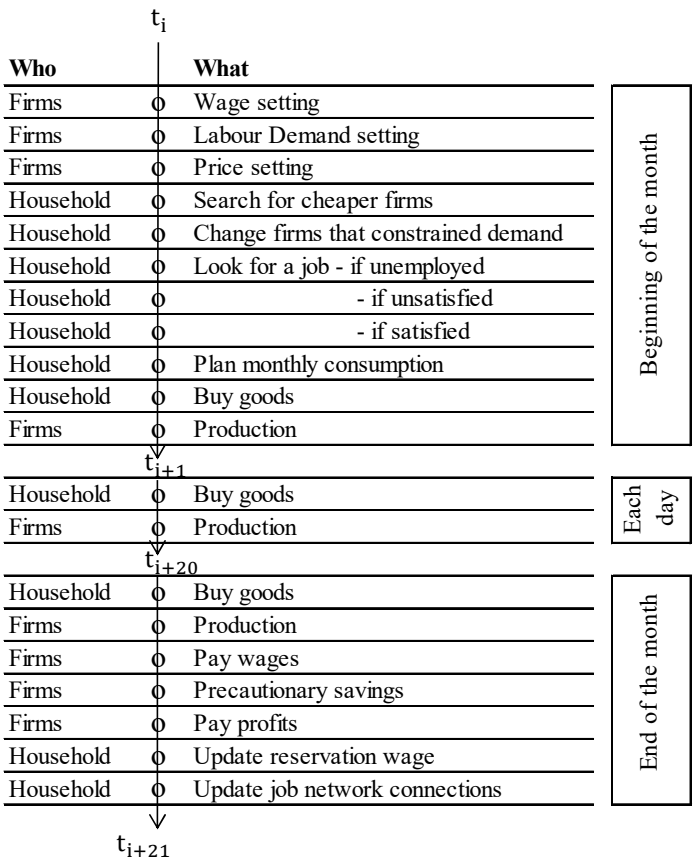
[15] Additionally, the data used in most of the recent research is richer than ours, therefore, it is harder to identify the parameters of a more complex model with Colombian data.

run firm size is approximated, based on the observed distribution of sizes within each sector ($P_{sector,size}$). Moreover, we do not impose any structural differences between formal and informal firms of the same size within sizes 1-10 workers, therefore, for these firms, it must be satisfied that:

$$tfp_{formal,size} = tfp_{informal,size} \quad \forall\ size = \{size_1, size_{2-3}, size_{4-5}, size_{6-10}\} \qquad (2)$$

For firms with 11 or more workers we allow for potentially different productivities for formal and informal firms to account for large firms' size differences in each sector. These assumptions imply a set of six possible $tfp_{sector,size}$ unique values but also allow for the overlapping of productivities between sectors and higher wages on average in the formal sector.

Figure 3.4 Timing of activities of each month



Source: Author's elaboration based on Lengnick (2013)

Initially, Type A and Type B connections are created at random assuming that all households are employed. If workers are assigned to a(n) (in)formal firm, then they receive the firm's (in)formal status. After this random allocation of goods and labour connections is done, up to ten Type F connections are created between households based on their Type B connections. More specifically,

for each worker i, a co-worker j is picked at random to establish an undirected connection. In this case, the adjacency matrix capturing the connections (g), besides being symmetric (that is, $g_{ij} = g_{ji}$), is weighted, with weights equal to the number of months remaining for the connection to expire (g_{ij}).

After objects and connections have been set up, activities begin following the monthly schedule in Figure 3.4, which we describe in detail next.

Firms- Rule 1 (Wage setting)

At the beginning of each month, firms decide their wage (w_f). A firm increases w_f if there are unfilled vacancies from the previous month. Conversely, the firm decreases w_f if all vacancies have been filled successfully for more than γ months. If none of these conditions are met, there is no wage change. The adjustment is given by:

$$w_{f,t+1} = \begin{cases} w_{f,t}(1+\mu) & \text{if } vacancy_{f,t} = TRUE \\ w_{f,t}(1-\mu) & \text{if } \gamma_{f,t} > \gamma \\ w_{f,t} & \text{else} \end{cases} \qquad \mu \sim U(0,\delta) \qquad (3)$$

where the random variable μ is uniformly distributed in the interval $(0,\delta)$ and $\gamma_{f,t}$ captures the months the firm has been filling its vacancies.

Firms- Rule 2 (Labour Demand setting)

At the beginning of a month and after wages are adjusted, firms decide their workforce size depending on their inventories ($i_{f,t}$). Each firm has upper ($\overline{i_{f,t}} = \overline{\phi} d_{f,t}$) and lower levels for inventories ($\underline{i_{f,t}} = \underline{\phi} d_{f,t}$) which depend on the previous month's demand ($d_{f,t}$). If inventories have fallen below the lower bound, $\underline{i_{f,t}}$, a vacancy is created ($vacancy_{f,t} = TRUE$).

If inventories are above the upper bound, $\overline{i_{f,t}}$, a randomly chosen worker is fired by the end of the month ($tofire_{f,t} = TRUE$). If inventories are between the lower and upper bounds, the firm cancels all previous firing and hiring decisions ($tofire_{f,t} = FALSE$ and $vacancy_{f,t} = TRUE$).

Firms- Rule 3 (Price setting)

At the beginning of a month and after labour demand has been adjusted, each firm decides its price ($p_{f,t}$) depending on its level of inventories ($i_{f,t}$) but also on profit margins for each good sold. If

inventories ($i_{f,t}$) are below the lower bound ($\underline{i_{f,t}}$) the firm considers increasing p_f and conversely, if they are above the upper bound ($\overline{i_{f,t}}$) the firm considers reducing $p_{f,t}$. Each firm has upper $\left(\overline{p_{f,t}} = \overline{\varphi} cmg_{f,t}\right)$ and lower $\left(\underline{p_{f,t}} = \underline{\varphi} cmg_{f,t}\right)$ levels for $p_{f,t}$which depend on marginal costs ($cmg_{f,t}$) In this case, given the daily production technology of each firm (see Firms-Rule 4), marginal costs are given by $cmg_{f,t} = \frac{w_{f,t}}{21\eta\lambda_f} L_{f,t}^{1-\eta}$, where λ_f is the total factor productivity (TFP). Prices are raised as long as they do not exceed the upper level ($\overline{p_{f,t}}$), and decreased as long as they are above the lower level ($\underline{p_{f,t}}$). Lastly, following Calvo (1983), a price change only takes place with a probability $\theta < 1$. The adjustment is given by:

$$p_{f,t+1} = \begin{cases} p_{f,t}(1+\nu) & \text{if } i_{f,t} < \underline{i_{f,t}} \text{ and } p_{f,t} < \overline{p_{f,t}} \text{ and } \theta_{f,t} < \theta \\ p_{f,t}(1-\nu) & \text{if } i_{f,t} > \overline{i_{f,t}} \text{ and } p_{f,t} > \underline{p_{f,t}} \text{ and } \theta_{f,t} < \theta \\ p_{f,t} & \text{else} \end{cases} \quad \nu \sim U(0,\vartheta) \qquad (4)$$

Where $\nu \sim U(0,\vartheta)$ and $\theta_{f,t} \sim U(0,1)$ are uniformly distributed random variables.[16]

Households- Rule 1 (Search for cheaper firms)

At the beginning of a month, and after firms have adjusted prices, each household is picked in random order to search for firms offering cheaper consumption goods. Each household picks one random firm from those it has a Type A connection with, it also picks a random firm from those outside its Type A connections, with the probability of picking one proportional to the firm's size measured in employees. The household compares if $p_{f,t}$ of the new firm is ε percent lower than that of the existing firm and changes the connection if that is the case. The entire process is only carried out with a probability $\psi_{price} < 1$.

Households- Rule 2 (Change firms that constrained demand)

At the beginning of a month, and after households have searched for cheaper firms, each household is picked in random order to change firms that restricted their demand over the previous month because of low inventories. Each household picks one random firm from those with whom they have a Type A connection, with the probability of picking one firm proportional to the extent of the

[16] Assuming the profit function of each firm is $\pi_{f,t} = p_{f,t}\lambda_f\left(L_{f,t}\right)^{\eta} - w_{f,t}L_{f,t}$ at the optimum labour demand $p_{f,t} = cmg_{f,t} = \frac{w_{f,t}}{21\eta\lambda_f} L_{f,t}^{1-\eta}$.

constraint in the previous month. The link is changed to another new random firm from those outside its Type A connection. The entire process is only carried out with a probability $\psi_{quant} < 1$.

Households- Rule 3 (Look for a job if unemployed)

At the beginning of a month, and after households have changed firms that constrained their demand, each household is picked in random order to look for more beneficial labour market links. If the household is currently unemployed (off the job search), firstly, it decides whether to perform a direct search or an indirect search using their job contact networks. The latter is chosen with a probability $\rho < 1$. If the search is direct, a random firm is visited. Alternatively, if the search is through colleagues, contacts are visited at random until a vacancy outside its own firm appears or the Type F list has been exhausted. If a firm has a vacancy and its wage $w_{f,t}$ is above the household's reservation wage ($rw_{hh,t}$), a new Type B link is created between household and firm, the household status is changed to formal or informal depending on the status of the firm it is linking to, and the household stops its job search. If this is not the case, the search process is repeated up to five times.[17] [18]

Households- Rule 4 (Look for a better job if unsatisfied)

If the household is working but because of a wage cut, its reservation wage ($rw_{hh,t}$) is above its firm's wage ($w_{f,t}$), a job search is carried out (on the job search): with probability $\rho < 1$, contacts are visited at random until a vacancy appears or the Type F list has been exhausted. Alternatively, a direct search is attempted: a random firm is visited. If a firm has vacancies and $w_{f,t} > rw_{hh,t}$, a new Type B link is created between household and this new firm while the previous link with its old firm disappears. As before, the household status is changed to formal or informal depending on the status of the firm it is linking to.

Households- Rule 5 (Look for a better job if satisfied)

[17] In reality, individuals resort to a direct and an indirect search simultaneously. In the model we assume that both search mechanisms are perfect substitutes, and one mechanism is randomly selected to easily introduce the propensity of search with contacts that we found in the data. As will be discussed later, the propensity to use contacts in the Colombian economy is crucial for the results we find. More realistically, one could assume that individuals learn which type of search to implement from the size and composition of their own network or from their success in previous job search. Such an approach will increase the difficulty of the model by adding a higher degree of path dependence for job-search decisions.
[18] Note that the model omits for simplicity the use of Public Employment Service or online job intermediary platforms for job search. The first is almost irrelevant in Colombia and the second is not as prominent as in developed countries.

If the household is working and its current wage ($w_{f_{old},t}$) is above its reservation wage ($rw_{hh,t}$), the household looks for a better job only with a probability $\pi < 1$. If the household decides to search (on the job search), the process is exactly the same as if the household was unsatisfied. If the firm has vacancies and its wage ($w_{f_{new},t}$) is greater than its current wage (that is, it satisfies $w_{f_{new},t} > w_{f_{old},t}$), a new Type B link is created between the household and this new firm, while the previous link with its old firm disappears. As before, the household status is changed to formal or informal depending on the status of the firm it is linking to.

Households- Rule 6 (Plan monthly consumption)

At the beginning of a month, and after households have looked for more beneficial labour market links, households decide how much of their liquidity ($m_{hh,t}$) to spend on consumption goods.[19] It is assumed that monthly consumption, c_{hh_t}, is a function of real money holdings $m_{hh,t}/p_{hh,t}$:

$$c_{hh_t} = \min\left\{\left(\frac{m_{hh,t}}{p_{hh,t}}\right)^{\alpha}, \frac{m_{hh,t}}{p_{hh,t}}\right\} \tag{5}$$

where the price deflator $p_{hh,t}$ is the average price of goods in the seven firms the household buys from (that is, the seven firms each household has as Type A connection) and the parameter α, satisfies $0 < \alpha < 1$.

Households- Rule 7 (Buy goods)

After all the adjustments of the beginning of the month have finished, each household is selected at random to buy goods. A random firm from the set of firms the household has a Type A connection with is selected. If the firm's inventories are enough to satisfy the household's daily demand ($c_{hh,t}/21$) and the household has enough liquidity to pay for the purchase, the household's liquidity is reduced by $p_{f,t}(c_{hh,t}/21)$ while the firm's liquidity is increased by the same amount. The firm's inventories are reduced by $c_{hh,t}/21$, and the firm's demand is increased by the same amount. In the case of the household not having sufficient liquidity to pay for the purchase, its demand is reduced to the maximum amount it could buy: $m_{hh,t}/p_{f,t}$, and the previous steps are completed. If on the other hand, the firm's inventories are not enough to satisfy the household's daily demand,

[19] The function minimum is introduced to account for consumption plans outside the budget constraint in the case real money holdings satisfy $\frac{m_{hh,t}}{p_{hh,t}} < 1$

the purchase is reduced to the level of available inventories: i_f. The transaction is completed, but the household registers the amount of its constrained demand by the firm lacking inventories and the firm registers the intended demand of the household instead of the actual demand. Lastly, the constrained household picks another firm from its Type A connections to satisfy the remaining demand. This process of searching for another firm to satisfy remaining demand is carried out until all seven firms are visited or 95 percent of the daily demand plan has been satisfied. The buying goods process is carried out on each one of the 21 days of the month.

Firms-Rule 4 (Production)

After all households have bought goods, each firm increases inventories using a concave production technology:

$$i_{f,t+1} = i_{f,t} + \lambda_f \left(L_{f,t}\right)^{\eta} \tag{6}$$

where $L_{f,t}$ represents the number of households (workers) the firm has a Type B connection with, $\lambda_f > 0$ is a firm specific technology parameter (TFP) and η a common elasticity of output to labour. This production process is performed on each one of the 21 days of the month.[20]

Firms-Rule 5 (Pay wages)

At the end of the month, each firm pays wages to each household (workers) the firm has a Type B connection with. The firm's liquidity is reduced by $w_{f,t}L_{f,t}$ while each household increases its liquidity by $w_{f,t}$. If a firm's liquidity is below its payroll cost (that is, $w_{f,t}L_{f,t} > m_{f,t}$), the firm reduces its wage to $w_{f,t} = \frac{m_{f,t}}{L_{f,t}}$, all households accept this emergency wage cut and wage payment proceeds as before.

Firms-Rule 6 (Precautionary savings)

At the end of the month and after wages are paid, if each firm's liquidity is positive, the firm keeps a fraction of its liquidity as precautionary savings for paying wages in an adverse market. This fraction is equivalent to $\chi w_{f,t}L_{f,t}$ with $\chi > 0$.

[20] The strictly concave production function is a modification from the original Lengnick (2013) paper. It is an assumption made to reduce wage and price dispersion by making the marginal product of labour high when employment in each firm is low.

Firms-Rule 7 (Pay profits)

At the end of the month, after wages are paid and precautionary savings have been made, each firm's remaining liquidity is distributed among households as profits. The share of each household in a firm's profits is proportional to each household's liquidity relative to all households.

Households-Rule 8 (update reservation wage)

At the end of the month, and after wages and profits are paid, each household updates its reservation wage $rw_{hh,t}$. If the household is currently unemployed, it reduces its reservation wage by rw_{red} percent. If the household is employed and its current wage is above the reservation wage (that is, $rw_{hh,t} < w_{f,t}$) the household updates its reservation wage to its current wage; in the opposite case ($rw_{hh,t} \geq w_{f,t}$), the household does not change its reservation wage.

Households-Rule 9 (update job network connections)

At the end of the month, and after households have updated their reservation wage, each household checks each one of its job contact connections. If a contact j is no longer in a household $i's$ firm or household i is unemployed, the weight g_{ij} in the adjacency matrix is reduced by one unit (month); if any weight reaches zero, the connection disappears. After household i ages its job contact network, if it has less than 10 Type F connections and it is working, it randomly picks a co-worker j to create a new connection with. Provided that j is not already in i's Type F connections and that j has less than 10 Type F connections as well, an undirected link is created between both households and the weight in the adjacency matrix (g_{ij}) is set to ζ months, with $\zeta \sim U(0, \overline{\zeta})$.

An overview of networks in the model

Notice that Type A and B connections change according to the profitability of the link for households, that is, whether a firm is offering a required amount of goods at a comparatively low price or offering a comparatively high wage in exchange for labour. Type B ties could also be severed by a firm depending on profitability, that is, if inventories are higher than expected, a random worker is fired. On the other hand, no economic incentive determines the updating process of Type F networks. Given that job contacts are usually acquired on the job, new links with other households (workers) at the same firm are made at random. The only requisite for mutual consent in the link

formation is bilateral room for a new contact in each worker Type F list.[21] Notice that within the model, Type F connections are assumed as weak ties: they suffer a process of aging that could potentially lead to link destruction, with the time the connection is alive after one of the households (workers) moves to another firm being uniformly distributed. This setup allows new links to be created, while keeping the size of Type F connections manageable and disciplined by firm size. In practice, the aging process captures the fact that when looking for a job, an individual is more likely to turn to acquaintances they have seen more recently as opposed to connections they have not interacted with for several years. Lastly, it is worth noting that networks are not used for referral hiring as in some of the economic literature discussed, but for the discovery of job openings.

When two connected households i and j are no longer in the same workplace, their link could generate positive and negative externalities. The connection works as a bridge to a potential better employment outcome (higher wage or employment in case unemployed) or in the case i or j are unemployed it could lead to an unsuccessful job search. Suppose worker j moves to a better paid job, this movement generates a positive externality for its contact i: if the firm is expanding and i is either unsatisfied or randomly decides to search for a job despite being satisfied, worker i could end up in a better paid job in j's firm. An opposite result arises if j moves to unemployment. Given that households look for a vacancy within their entire Type F list, and that those households are also looking for a better outcome themselves, we could think of job-contact networks as an indirect way of searching for a better labour market outcome. Lastly, increasing the time duration of the link ζ or the number of Type F connections increases information inflows for any worker, making job contact search with networks more effective. However, it is expected that these additional benefits are marginally decreasing because of congestion in the use of networks.

In our model, there are two additional aspects to consider, firm size and the informality divide for firms and workers. Higher productivity implies higher wages for formal relative to informal firms but also, formal firms will have bigger payrolls on average, and consequently a bigger pool of job contacts for its workers. Two extreme cases highlight the main implications of the model setup for these dimensions. Suppose that all firms are unipersonal on average. The scope of network

[21] Notice that in our ABM, keeping contacts is not costly but there is an upper bound on their number. This assumption departs from models of strategic network formation that require positive costs to bound the number of contacts.

formation in this case is null and job search through contacts will be useless given the size of job networks. Alternatively, suppose that the only search mechanism available is that of job contacts. This setup will reduce the movement of workers between firms and sectors to zero, de facto segmenting both markets as workers will only be connected to other workers in the same firm. Additionally, the lack of movement implies a greater divergence of wages between the two sectors as information on formal/informal wages will be transmitted for formal/informal households only. In the spirit of Granovetter's (1983) strength of weak ties, a varied pool of job contacts delivers better employment outcomes. However, the effect of the two search mechanisms (that is, direct and through job contacts) operating simultaneously remains to be seen. The above-mentioned features will guide our estimation decisions in the next section.

3.4.2 Estimation

To recreate the labour market in the Colombian economy, a set of 20 technology and job-search parameters from the model are applied to the data. The main goal is to capture those features that affect labour market outcomes and job contact networks, namely: firm size, worker flows, and the use of job contact networks. Admittedly, a high proportion of the model's parameters do not correspond to the Colombian economy and this might bias the parameters estimated and the conclusions drawn. However, considering the lack of data, we hope that, given the nature of the parameters not estimated (that is, mostly related to the clearing of the goods market), the bias will be minimal and will not considerably affect our findings.

To accommodate the labour market setup in the model, in which wage-earners constantly change firms, we exclude workers living in rural areas, self-employed workers without a business, domestic workers and workers without earnings. Regarding the informal sector, we follow a legalistic view and consider as formal workers those who declare making contributions to a pension fund in the survey.[22]

[22] Around 10% of workers belong to rural areas. 37% are self-employed, however, we keep those self-employed workers with a business to include the employer population equivalent to 8% of the worker force. Domestic workers account for around 3% of workers. The workers without earnings group comprises family workers and workers in private firms without earnings. The group accounts for 3.5% of workers

Table 3.2 Distribution of workers and firms by size (in workers) and formality status

		Informal Sector					Formal Sector					Total
Data	Number of workers per firm	1	2-3	4-5	6-10	11+	1	2-3	4-5	6-10	11+	
	Share of workers*	8.0%	16.4%	6.6%	4.6%	6.2%	0.8%	2.5%	2.3%	3.6%	49.1%	100%
Model	Workers	80	164	66	46	62	8	25	23	36	490	1000
	Firms	80	66	15	6	3	8	10	5	5	11	209
	Share of Firms ($P_{sector,size}$)	38.3%	31.6%	7.2%	2.9%	1.4%	3.8%	4.8%	2.4%	2.4%	5.3%	100%
	Worker inf/form rate			41.8%					58.2%			100%
	Firm inf/form rate			81.3%					18.7%			100%

Source: Authors' own calculations based on GEIH 2010-2018 and Confecamaras (2016), for the model, numbers are rounded to the nearest integer. *average monthly shares for the 9-year period.

Given the lack of comprehensive firm data for Colombia, we use each worker's reported firm size to compute the share of workers within each type of firm as presented at the top of Table 3.2. Notice that answers to the firm's size question are in interval form in the survey. [23] Assuming that firms are composed entirely of formal or informal workers, we can use this worker information to recover the number of firms of each size by dividing the number of workers in each category by the reported size.[24] At this point, we arbitrarily assume 1,000 households employed for the model and distribute them according to the observed shares. Next, we divide the number of workers within each cell by the reported size to obtain the approximate number of firms shown in Table 3.2. More specifically, for the closed intervals we use their mid-point as the effective number of workers.[25] Considering the right-open interval nature of the size of the largest firms, we make the following assumptions: for the formal sector, we use a register of formal firms (Confecamaras, 2016) to obtain the number of firms with 11 or more workers (small, medium and large firms in Colombia) and

[23] In the survey, each worker is asked: How many people are employed at the firm, business, or industry where you work? With the answer restricted to the intervals 1 worker, 2-3 workers,4-5 workers, 6-10 workers, 11-19 workers, 20-30 workers, 31-50 workers 50-99 workers and 100 or more workers.

[24] Ulyssea (2018) employs Brazilian firm data to show that this assumption is not necessarily the case, but that firms also decide on an intensive margin of informality, that is, how many formal and informal to hire. The opposing assumption in our model, despite being crucial for the behaviour of the network, is done to keep things simple given the lack of firm data. Additionally, having firms deciding whether to hire a worker as formal or informal would imply an additional mechanism to make this decision, such as the increasing cost of non-compliance in Ulyssea's (2018) work.

[25] The number of workers and firms was rounded to the nearest integer; this will result in small discrepancy in the average size of firms within each category.

approximate their number in the model to 11 firms.[26] Given the lack of data for large informal firms, we estimate a Pareto distribution of firm size for firms with 10 or less workers. With the resulting distribution, we estimate at three the number of large informal firms in the model.[27]

From the worker perspective, the distribution by firm's size and formality status is correct by construction given the representativeness of the GEIH. The number of firms ($n_f = 209$) and distribution is in line with previous literature. For instance, Fernandez (2018) found that there are almost 2 million businesses in the country (equivalent to roughly 200 in the model), with most of them (63 percent) comprising single person firms (42 percent in the model) and an informality rate of around 60 percent using the firm's registry as an indicator of formality (81.3 percent in the model using pension contribution of workers as indicator of formality).[28]

We define the vector of model's parameters as $\Theta = \{\Theta_{fix}, \Theta_{obs}, \Theta_{est}\}$ consisting of three components: parameters fixed, with values taken from the original Lengnick (2013) model,[29] parameters observed and parameters estimated. The vector $\Theta_{obs} = \{P_{se,si}, \rho, n_f, n_{hh}\}$ comprises 13 parameters: the distribution of firms by size and sector, the probability of using job contacts in on the job search and the number of firms, which are taken from the data and directly plugged into the model.[30] Given that the model comprises working and unemployed households, we fix $n_{hh} = 1{,}014$ taking into account 1,000 workers and a frictional rate of unemployment of around 1.4 percent. Without loss of generality, we normalise $tfp_{formal,size_1} = tfp_{informal,size_1} = 1$. This assumption and the one in Equation 2 give us a vector of 7 parameters to estimate, comprising five productivities and the probabilities of on the job search and the maximum time-length of each connection $\Theta_{est} = \{tfp_{se,si}, \pi, \bar{\zeta}\}$.

[26] Confecamaras registered 106,267 firms with 11 or more workers. This roughly corresponds to 11 firms in the model given the ratio of one worker in the model to 10,000 workers in the survey. For the model, there are 491 workers in firms with 11 workers or more and therefore the average formal size for this group is 45 (rounding 44.63) workers.

[27] We use the information on the distribution of firms by size up to 10 workers to estimate the shape parameter (α) of a Pareto distribution. We obtain $\alpha = 1.74$, with this, and the pdf we observe that the firms remaining account for 1.7% of the firms (3 firms) corresponding to an average firm size of 21 for the 62 workers in this category.

[28] This is a less stringent definition of firm informality as paying payroll taxes such as pension contribution is more expensive for firms than registering the firm (Fernandez, 2018).

[29] Ideally, one would estimate the entire set of parameters for the model, however, the high number of them entering the model makes it almost impossible to do it. We stick with some of the parameter values from the original Lengnick model because in the theoretical exercise the parameters used gave sensible results on the behaviour of the macroeconomic model.

[30] In the data we observe the proportion of unemployed households using job contacts, whereas in the model we use this as the individual probability of using job contacts for both off and on the job search.

These parameters are estimated using simulated minimum distance (Grazzini and Richiardi, 2015) while the remaining comprises the vector of parameters fixed Θ_{fix} (see Tables 3.3 and 3.4). [31]

Table 3.3 Fixed parameters and initial conditions

Parameter	Value	Description
Household parameters		
α	0.9	Parameter consumption function
ε	0.01	Par. to check price for changing Type A connec.
ψ_{price}	0.25	Prob. of checking type A con. (cheaper firms)
ψ_{quant}	0.25	Prob. of checking type A con. (constrained)
β	5	Number of firms to check if unemployed
n_{TypeA}	7	Number of Type A connections
n_{TypeF}	10	Maximum number of Type F connections
n	7	Number of firms to visit
rw_{red}	0.1	Perc. reduction in reservation wage unemployed
Firm parameters		
δ	0.019	Parameter random increase or decrease wage
$\overline{\phi}$	1	Parameter in upper bound in inventory
$\underline{\phi}$	0.25	Parameter in lower bound in inventory
$\overline{\varphi}$	1.15	Parameter in upper bound in price
$\underline{\varphi}$	1.025	Parameter in lower bound in price
ν	0.02	Parameter random increase or decrease price
θ	0.75	Parameter to proceed with price change
η	0.9	Parameter of elasticity of output to labour
χ	0.1	Wages-buffer ratio
γ	1	Limit months to decrease wage

Parameter	Value	Description
Household initialisation		
rw_{hh}	0	Reservation wage
m_{hh}	100	Liquidity for households
$employed_{hh}$	TRUE	All households are employed
Firm initialisation		
p_f	1	Price
w_f	50	Wage
m_f	0	Liquidity for firms
i_f	500	Inventories
γ_f	0	No months with filled vacancies
d_f	500	Demand from last month
$vacancy_f$	FALSE	No vacancies
$tofire_f$	FALSE	No firing decisions
$hired_f$	0	No new hires
Model initialisation		
burn_in	300*12*21	Burn-in periods (in days)
end_time	800*12*21	End of simulation (in days)

Source: Author's elaboration based on Lengnick (2013)

Admittedly, we have omitted two important parameters from the estimation process: the elasticity of output to labour (η) and the maximum number of Type F connections ($nTypeF$). For the former, we do not have additional information on the returns to scale of Colombian firms. We observe an inverse relation of this parameter and the five firm productivities ($tfp_{se,si}$), but we have not been able to identify it and we assume a value of 0.9 and do some sensitivity analysis. More importantly, for the maximum number of job contacts we also do not have additional information. We expect that the efficiency in the use of contacts increases with $nTypeF$ and also, with the maximum time-length of each connection ($\overline{\zeta}$). After some exploratory analysis with the model, we found that at least seven contacts are necessary to reach the efficiency in use of contact implied by the Colombian data and therefore, we fix $nTypeF = 10$ allowing a sensible (not too high) value of $\overline{\zeta}$ to be recovered from the estimation. We further discuss this matter in Section 3.5.

[31] In practice, we re-estimate the parameters of the model for integer values around $n_{hh} = 1014$ to make sure the long-run number of employees is as close as possible to 1,000. This manual estimation is carried out given the integer nature of the variable n_{hh} which complicates its estimation by simulated minimum distance. We also check that variables to be estimated do not considerably affect the frictional unemployment rate.

The estimation process of Θ_{est} is as follows: we create a vector of 7 moments. Total number of workers within each size excluding firms of 1 worker (5 moments).[32] [33] The probability of job-to-job transition, and the probability of a new position found through networks.[34] [35] The moments chosen are informative of the parameters to be estimated: the values of the $tfp_{sector,size}$ are identified from the distribution of firm sizes, while the probability of on the job search and the length of each connection (that is, π, ζ) are identified from the observed job-to-job transition rate and the share of new jobs found through contacts respectively. For the former, a higher π (probability of on the job search) implies, ceteris paribus, a higher job-to-job transition rate. On the other hand, increasing the maximum length of each connection ($\bar{\zeta}$) makes the use of contact networks more effective, bringing a higher volume of job opening information from workers with very divergent work trajectories (that is, working in different firms), implying a higher share of new jobs obtained through networks.

From the model's point of view, the vector of simulated moments $M_s(\Theta)$ is an unknown function of the vector of parameters Θ including the random seed. We numerically approximate these moments by computing long-run averages of the underlying variables at each model run. An observed vector of moments $\widehat{M}$ is estimated from the survey data to compute the objective function $Q(\Theta)$:

$$Q(\Theta) = \left(\widehat{M} - M_s(\Theta)\right)' W \left(\widehat{M} - M_s(\Theta)\right) \tag{7}$$

where W is a positive semi-definite matrix. An estimator for the set of parameters $\widehat{\Theta}_{est}$ is obtained by minimising the objective function in 7 changing Θ_{est}:

$$\widehat{\Theta}_{est} = \underset{\Theta_{est}}{\operatorname{argmin}}\, Q(\Theta) \tag{8}$$

We assume that W is a diagonal matrix in which $W_{ii} = \left(\frac{1}{\widehat{M}_i}\right)^2$, this implies $Q(\Theta)$ is the unweighted sum of the squares of the percent deviations of each moment from its observed value.

[32] The reason behind this exclusion is the model assumption of no entry or exit of firms that does not allow for firms of this type to exhibit less than one worker. This makes the use of this moment inadequate. Notice that the inclusion of this moment is not necessary as the system is identified.

[33] We omit the share of formal workers from the list of moments, as its value will be achieved by targeting the size moments.

[34] These are computed at a monthly interval in the data and the model.

[35] From the data, this includes networks of relatives, friends, and colleagues, in the paper the focus is on friends and colleagues, this equates to the Granovetter's (1973, 1983) assumption that information on job openings of relatives or very close friends overlaps with the information one already has.

The minimisation process of $Q(\Theta)$ is as follows: firstly, the vector of parameters $\Theta_{fix}, \Theta_{obs}$ and the initial values of control variables are set to their respective values. Next, for an initial (arbitrary) value of the vector of parameters to be estimated Θ^0_{est}, the model is run for 800 years (9,600 months) including an initial burn-in of 300 years to reduce the effect of arbitrary initial condition for control variables.[36] The number of periods (500 years) is sufficiently long to compute the long-run mean of variables, especially considering that some moments are outcomes at the meso-level, that is, groups of firms. The vector of moments $M_s(\Theta^0)$ and objective function $Q(\Theta^0)$ are computed and jointly determine the next vector of parameters to be evaluated Θ^1_{est}. The process is repeated until a stopping criterion is met.

The estimation procedure is carried from different initial points to avoid convergence to any local minima.[37] Given that each model run is computationally expensive and the unknown nature of the objective function, especially regarding differentiability, we use the derivative free minimisation algorithm BOBYQA (Powell, 2009) to minimise the function. The algorithm computes a quadratic approximation of the objective function for a user-provided number of interpolation points. It also accepts bounds on variables.[38] [39]

3.4.3 Results

The estimated parameters and moments for the Colombian economy are presented in Table 3.4 and Figure 3.5, respectively. For the set of parameters, we observe that productivities increase with firm size, including higher productivities for large formal firms relative to large informal firms. We also find that the average duration of a connection is around 4 years, assuming the underlying variable ζ is uniformly distributed (that is, $\zeta \sim U(0,98.06)$). If workers are satisfied with their job, they must search for a better one almost ½ of the time. The targeted moments are relatively well matched by the estimation, with minor differences in the firm size moments. For both data and

[36] An overview of the effects of arbitrary values for variables on the behaviour of the model in the burn-in period is discussed in the appendix.

[37] JAS-mine, a Java platform that aims to provide a unique simulation tool for discrete-event simulations is used for the exercise. See Richiardi and Richardson (2017) for more information.

[38] Each one of the 800 years run of the model takes 310 seconds on a W10 machine with an Intel Xeon processor E5.

[39] The version used is included in the Java Library Apache Commons Math.

model, close to 52 percent of jobs are obtained with contacts, and the probability of making a job-to-job transition is 0.88 percent.

In the long-run, the model reaches a state close to a general equilibrium regardless of initial conditions for control variables.[40] Almost all demand for goods is satisfied, there are simultaneously a positive number of unemployed households and vacancies, and prices converge dynamically to a well-behaved distribution of values instead of a single point as in traditional general equilibrium models. The model exhibits endogenous business cycles because agents only possess local information of the price formation and therefore, coordination failures lead to temporary mismatches in both markets.

Table 3.4 Parameters observed and estimated for the Colombian Economy

Variable	Value	Status	Description
n_{hh}	1014	Fixed	Number of households in the model[41]
n_f	209	Observed	Number of firms in the model
$P_{i,1}$	0.383	Observed	Probability of picking an informal firm with one worker
$P_{i,2-3}$	0.316	Observed	Probability of picking an informal firm with 2-3 workers
$P_{i,4-5}$	0.072	Observed	Probability of picking an informal firm with 4-5 workers
$P_{i,6-10}$	0.029	Observed	Probability of picking an informal firm with 6-10 workers
$P_{i,11-}$	0.014	Observed	Probability of picking an informal firm with 11 or more workers
$P_{f,1}$	0.038	Observed	Probability of picking a formal firm with one worker
$P_{f,2-3}$	0.048	Observed	Probability of picking a formal firm with 2-3 workers
$P_{f,4-5}$	0.024	Observed	Probability of picking a formal firm with 4-5 workers
$P_{f,6-10}$	0.024	Observed	Probability of picking a formal firm with 6-10 workers
$P_{f,11-}$	0.053	Observed	Probability of picking a formal firm with 11 or more workers
ρ	0.406	Observed	Probability of using job contact networks when searching for jobs
π	0.524	Estimated	Probability of checking type B connection if satisfied
$\bar{\zeta}$	98.06	Estimated	Maximum length (months) of each Type F connection
$tfp_{s,1}$	1.000	Estimated	TFP of a firm with one worker (Fixed)
$tfp_{s,2}$	1.337	Estimated	TFP of a firm with 2-3 workers
$tfp_{s,3}$	1.414	Estimated	TFP of a firm with 4-5 workers
$tfp_{s,4}$	1.492	Estimated	TFP of a firm with 6-10 workers
$tfp_{i,5}$	1.652	Estimated	TFP of an informal firm with 11 or more workers
$tfp_{f,5}$	1.790	Estimated	TFP of a formal firm with 11 or more workers

Source: Authors' own calculations

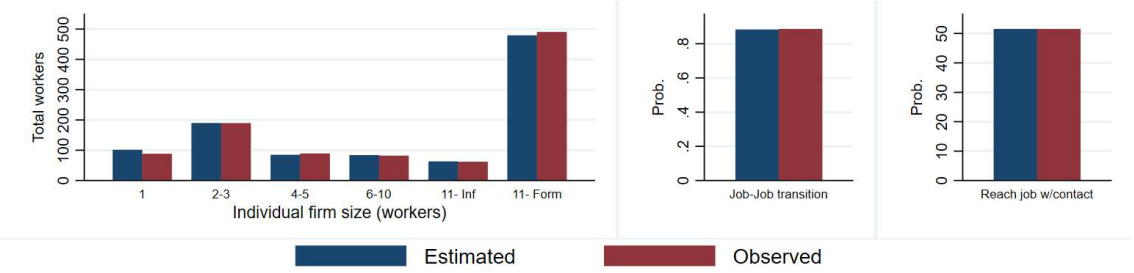
The first moments of important variables of the model such as employment, output or prices are ergodic. The moments used for estimation are ergodic and stationary. Small changes in the value of parameters lead to significant changes in the objective function implying that the seven estimated

[40] See Appendix 1.

[41] The original Lengnick (2013) paper proposes $n_{hh} = 1000$ and $n_f = 100$, our numbers try to accommodate the structure of the model to these sizes.

parameters are disciplined by the moment set chosen. All these checks and the methodology used to make them are presented in the Appendix.

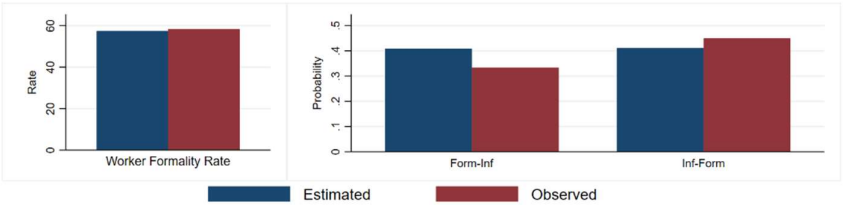
Figure 3.5 Estimated and observed moments



Source: Authors' own calculations, probabilities are expressed in a 0-100 scale. Notice that firms with one worker were not targeted.

Other model moments not targeted are also similar to observed values in the data as presented in Figure 3.6. The probability of making a transition between sectors or the worker formality rate are near the values observed. Nevertheless, we observe a slightly higher movement from the informal towards the formal sector, while the model generates cross-sector movements of similar magnitude. Differences in firm productivities generate a wage gap at worker level of around 10 percent, with the actual value using the methodology described in Section 3.2 standing at close to 20 percent for the period analysed. This implies that half the wage gap is accounted for by unobserved worker characteristics.

Figure 3.6 Fit of not targeted moments



Source: Authors' own calculations, probabilities are expressed in a 0-100 scale.

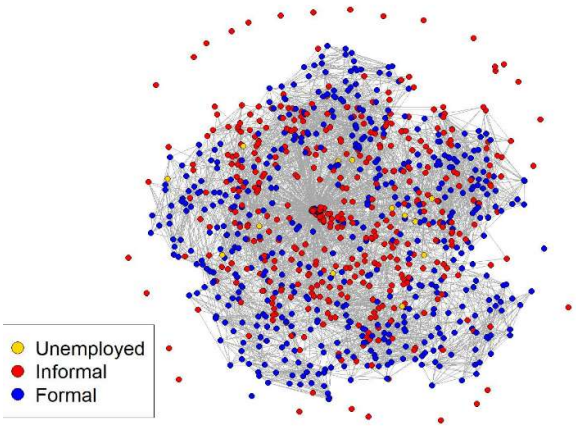
Networks

The network of job contacts (Type F connections) distinguished by the labour status of households for the last simulated period is presented in Figure 3.7. The average number of connections is 8.37,

being higher for formal (9.60) than for informal workers (6.96). We observe 71 unconnected nodes, with 92 percent of them in the informal sector. This result is expected, given that this sector captures most firms with just one worker in the data. It also highlights the importance of taking firm size into account in the setup of job contact networks. While the average number of contacts for workers in firms with 1 and 2 workers is 1.8 and 6.0, respectively, the average number of contacts is above 9.5 for workers in firms with 11 or more workers.

We also find clustering of nodes by sector, with informal workers having 70.3 percent of connections in their sector on average, and formal workers with 81.5 percent of connections in their sector on average. Additionally, the share of cross-status links is around 24.3 percent; in the case of non-homophily (that is, a completely random network) this value should be around 51.6 percent, indicating a relatively high degree of homophily in the job contacts network, that is, workers' contacts mostly work in the same sector.

Figure 3.7 Job contact networks



Source: Authors' own calculations for last period of one simulation

Despite the high degree of homophily, workers move relatively freely between sectors in search of better job opportunities. If we take an informal worker at the beginning of the simulation period (that is, at year 300) and follow him for 500 years, we observe that, on average, he works 52.8 percent of the time for a formal firm, and 45.7 percent of the time for an informal firm. These values roughly coincide with the proportion of households in each sector in the economy. Results for an initially formal worker are 59.2 and 39.48 percent respectively, indicating some advantage of formal workers in getting formal jobs. Lastly, if we focus on households working initially in firms

sized 1-3 workers, the movement of workers across sectors is almost unchanged, implying that, despite having few job contacts, workers eventually move to better paid jobs in bigger firms. In the next section, we go further and simulate the economy for different values of the parameters affecting the job contact network to test if the use of contacts has some effect on the real economy.

3.5 Counterfactual exercises

With our ABM that approximates the labour market and production in the Colombian economy, we now study the effects of network features and its use on the formal-informal divide. We explore the effects of changes in the propensity of use of contacts in the job search (ρ), but also, the substitutability of the maximum number of contacts (nTypeF) with the maximum duration of connections ($\bar{\zeta}$) given the impossibility of identifying both values simultaneously in the estimation. For the remaining, we focus on long-run means for model variables using the same run time as in the estimation (800 years), unless otherwise stated.

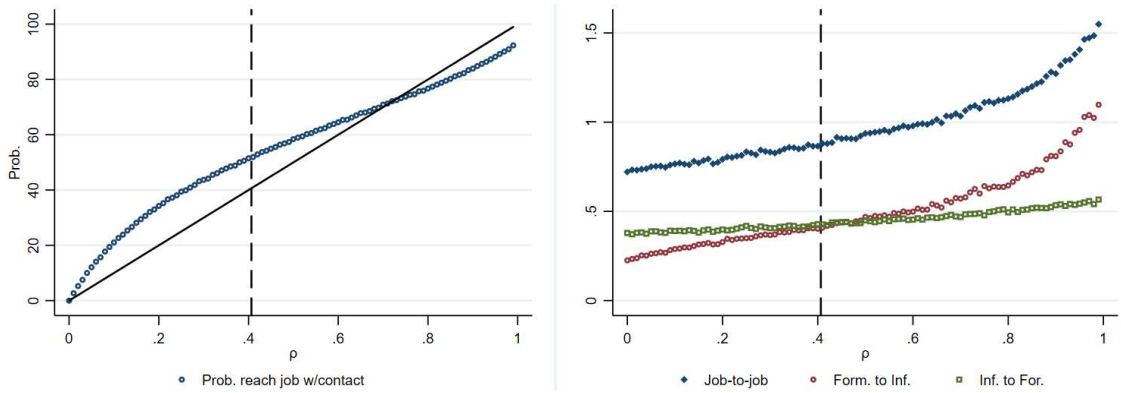
3.5.1 Changes in the propensity of use of contacts

We begin by simulating a 10 percent (4.06 pp) increase in the probability of using contacts for job search (ρ). We observe that the probability of obtaining a job with contacts increases around 6.2 percent implying congestion of using job contacts. The probability of a job-to-job transition increases by 2.7 percent and conversely, the average tenure of a job decreases from 82.4 to 81.3 months. The long-run value of variables such as output, employment, the wage gap between sectors and the worker formality rate remains almost unchanged.

An extension of the analysis for the entire range of values $\rho \in [0,1)$ is presented in Figure 3.8. From the first pane, we observe that increasing the probability of using contacts increases the probability of finding a job with them. However, the relation is far from linear: the efficiency of indirect search increases when the use of contacts is low, but decreases with higher usage, it being more effective to attempt a direct search when usage of contacts is above 73 percent. From the second pane, we observe that the exit rate from a job is always increasing in ρ. More specifically, the job-to-job transition rate, and the formal to informal job transition rate seem to be marginally increasing for high values of ρ. However, this result is greatly affected by changes in the composition of sectors (that affects the denominator) and not by increases in the number of transitions (numerator), as

described below. The variations in transition rates result in changes in real variables, especially wages.

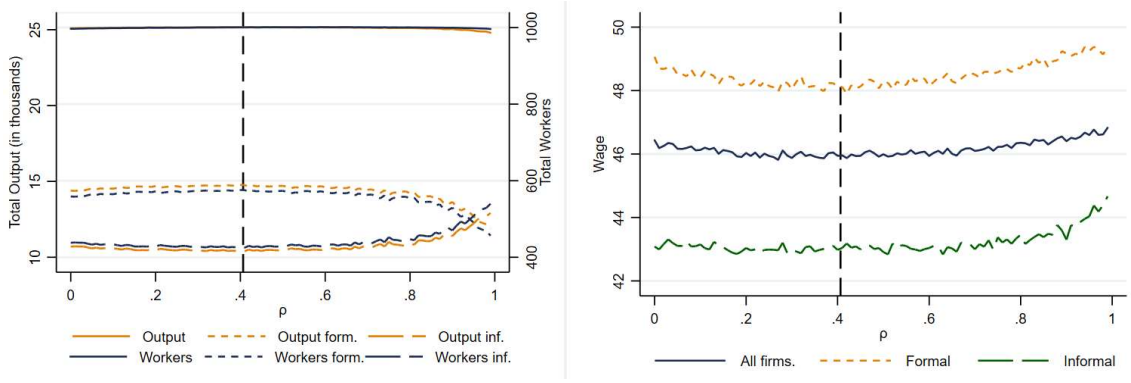
Figure 3.8 Effects of changes in the probability of using contact networks (ρ)



Source: Authors' own calculations. Probabilities are expressed in a 0-100 scale. Fitted value at the vertical dotted line.

Figure 3.9 presents the effect of changes in the use of contact networks on aggregate variables of the Colombian economy. From the right pane, we observe that for higher values of ρ, further increasing this variable considerably increases the average wage for the economy, especially in the informal sector. The availability of more information on job openings makes transitions more frequent and puts pressure on firms to attract workers by increasing wages, which in turns increases transitions even more. We observe that for most values for ρ, output and employment do not change at the aggregate or sectoral level. However, the share of informal workers increases for very high values of ρ, and for values of this parameter above 90 percent the worker informality rate surpasses that of formal work. The key takeaway from this result is that more information increases the chances of moving to better paid jobs, and informal firms try to catch-up with higher wages in the informal sector increasing, in the end, their share of employment. This re-composition of the economy towards informal activities leads to a (marginal) drop in total output, as a result of lower productivities in the informal sector and an almost unchanged employment rate.

Figure 3.9. Effects of changes in the probability of using contact networks (ρ)



Source: Authors' own calculations. Wages averages at worker level. Fitted value at the vertical dotted line.

An important advantage of ABMs over traditional equilibrium models is that our methodology enables the study of the effect of exogenous changes at the micro-level for a heterogeneous population. In Table 3.5 we study the effect of changes in the probability of using contact networks (ρ) on the probability of making a transition between formal and informal sectors. More specifically, we create 20 counterfactual scenarios in which we increase ρ in 5pp steps over its entire domain. Based on these scenarios, we create a sample consisting of monthly labour information for each one of the 1,014 households over the 10-year period, starting at the end of the burn-in period. For each employed household we compute one month ahead transitions: between sectors (Model 1), from informal to formal sector (Model 2) and from formal to informal sector (Model 3).

Table 3.5 Linear probability models of sectoral transitions

	(1) Transition	(2) Transition Informal to Formal	(3) Transition Formal to Informal
ρ	0.00402***	0.00215***	0.00572***
	(26.63)	(9.61)	(27.89)
nTypeF	0.00075***	0.00096***	0.00029***
	(42.3)	(45.19)	(6.39)
Firm size	-0.00016***	-0.00031***	-0.00013***
	(-44.73)	(-28.0)	(-29.5)
Initially formal	0.00322***		
	(23.88)		
Constant	-0.00147***	-0.00101***	0.00394***
	(-9.76)	(-5.79)	(9.94)
Observations (Millions)	2.44	1.06	1.38
Adjusted R-squared	0.0015	0.0020	0.0014

Source: Authors' own calculations. Based on 20 counterfactual scenarios for ρ. Notes: t statistics in parenthesis, significance level: *** p<0.01

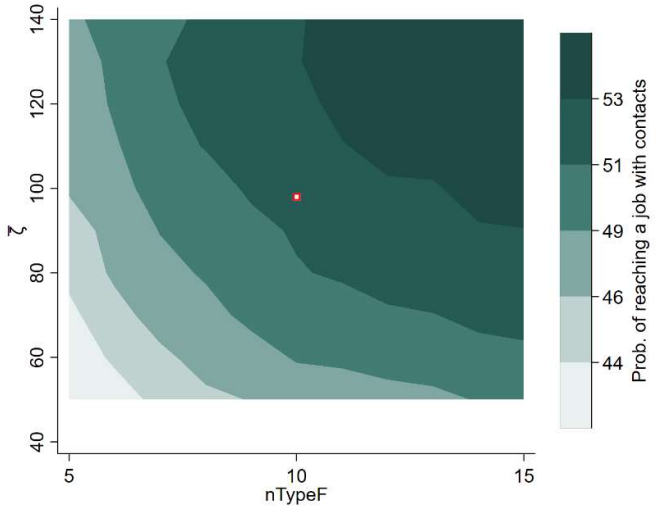
Our preferred specification for the models indicates that the effect of ρ on the probability of making a sectoral transition is positive, linear, and statistically and economically significant. A 10pp increase in ρ results in a 0.0402 pp increase in the probability of making a transition. To put things into perspective, at our baseline, the unconditional probability of making a sectoral transition stood at 0.44 percent, therefore, a 10pp increase in ρ increases by 9.1 percent the probability of a sectoral transition. As expected, the effect of firm size is negative, larger firms provide higher wages and therefore, the incentive to move is lower; having more contacts increases the chances of making a transition; and controlling for these two variables, those initially formal are more likely to move to the informal sector. Note that although the coefficients are statistically significant (probably because of the sample size) the proposed models only explain between 0.1 percent and 0.2 percent of the variability of sectoral transitions and there are other parameters or endogenous variables different than those related to networks that affect transitions considerably more.

3.5.2 Changes in the number and duration of connections

The estimation of the model was carried out under the assumption that the maximum number of contacts a household has is nTypeF=10. This allowed the maximum time for a TypeF connection ($\bar{\zeta}$) to be recovered from estimation by targeting the share of new positions found through networks. Figure 3.10 shows that for a given usage of contacts, ρ, both parameters, nTypeF and $\bar{\zeta}$ are substitutes in the production of matches using contact networks (that is, the moment targeted at estimation). The model also imposes some restrictions on the values of nTypeF that allow us to partially identify its value: from the graph, it can be seen that there is no value of $\bar{\zeta}$ that could result in a probability of obtaining jobs through contacts observed in the data (that is, 51 percent) if nTypeF is below seven contacts.

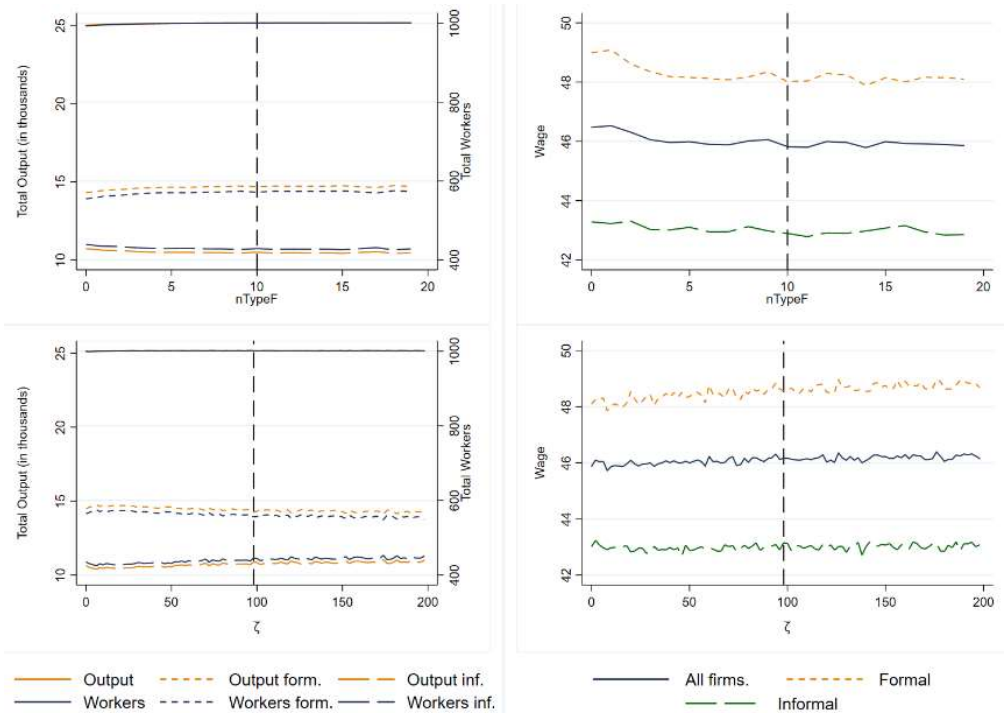
Despite the substitutability of the two variables, their effect on aggregate outcomes is dissimilar as observed in Figure 3.11, which presents the effects of changes in nTypeF and $\bar{\zeta}$ parameters on the main variables of the macroeconomic model. We observe that if the maximum number of contacts falls below three, there is a (marginal) drop in output and employment and an increase of wages. This could be the case as vacancies are left unfilled because using contacts is inefficient; firms increase wages in response to attract workers. For higher values of the variable, there are no important effects on output or wages.

Figure 3.10 Complementarity between nTypeF and $\bar{\zeta}$



Source: Authors' own calculations. Fitted value in red square.

Figure 3.11 The effect of changes in nTypeF and $\bar{\zeta}$ on the real economy



Source: Authors' own calculations. Wages averages at worker level. Fitted value at the vertical dotted line.

On the other hand, the value of $\bar{\zeta}$ has no important effect on aggregate output or employment, but for values of $\bar{\zeta}$ below a hundred (that is, 8.3 years) it has a reduced effect on the sectoral composition of these variables and on wages. Increasing $\bar{\zeta}$ from nil to its estimated value increases the share of informal employment by 1pp and wages in the formal sector by 1 percent.

3.6 Conclusions

This paper explored the effect of job contact networks on the informal-formal divide in Colombia, by means of a model able to capture the endogenous formation of contacts on the job. Previous studies on networks have highlighted the negative effects of job search through contacts for disadvantaged groups, resulting from their higher network homophily. We were mostly interested in the potential segmentation effects of the network homophily of Colombian workers.

Our exploratory ABM and its estimated parameters indicate that a higher use of contacts for job search is associated with a higher chance of being in the informal sector and having lower earnings. However, data limitations do not allow us to establish a causal relation between these variables. Our model, on the other hand, assumed homogenous households employed in heterogeneous formal and informal firms. Households have identical intensities for using networks for job search and could add contacts on the job. After adjusting the model to replicate the Colombian labour market, we found that acquiring contacts on the job creates segmented job networks and consequently a high degree of sectoral homophily: for the average household more than 70 percent of contacts are in the same sector. However, these conditions do not prevent workers from moving between sectors in search of better job opportunities because the observed propensity of using contacts is not relatively high. The current levels of direct and indirect job search allow workers to find jobs in distant parts of their own network through a direct search; this in turn benefits their contacts with information on better job openings.

There are several limitations of our framework that future research should address. First, we have not estimated some important parameters for the model, and this could potentially alter our findings. Admittedly, given the high number of the model's parameters and the lack of a data counterpart, this represents a huge challenge. Second, we have not introduced the heterogeneities of household surveys into the model. This is especially true for two important dimensions: skill level and differences in the propensity of the use of job contact networks. Improving on this could unite the ABM model developed here with the dynamic microsimulation approach that usually has a real-world database with information for model's agents as input. Lastly, we have not evaluated the uncertainty of our parameter estimates beyond a simple visual inspection. The introduction of an

optimal matrix of weights ($\mathbf{W}$) for the objective function and computing the variance-covariance matrix of the parameter estimates will necessarily improve our knowledge of the model.

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A.3 Appendix

A.3.1 Stationarity and Ergodicity

In this section we investigate the stationarity and ergodicity properties for the main aggregate variables of the model and for the moments used for estimation. Firstly, we describe the statistical test we use, then we present some descriptive statistics of selected variables for several simulation runs and results for the tests.

We follow Grazzini (2012) and extensively use the Runs Test, a non-parametric test usually employed to examine autocorrelation. Our strategy for each variable is as follows: we create monthly data for two model runs for 8,000 years based on two different random seeds. This large number of periods is needed to increase the power of the Runs Test. For each time series, we define windows (segments of the time series) of 1,000 months in length. Thus, the series is transformed from 96,000 months to 96 windows. Each observation in the new variable captures the mean of the underlying variable in that window.

Stationarity

With this new series, we create a dummy variable capturing whether the window mean is above or below the overall mean of the variable. Next, a Run is defined as "a succession of one or more identical symbols (i.e. 0 or 1) which are followed and preceded by a different symbol or no symbol at all" Gibbons (1985). For instance, in the series {0,0,1,0,0,1} there are 4 Runs {{0,0},{1},{0,0},{1}}. The Z statistic for the number of Runs is compared with its hypothetical value under a stationary series (Grazzini, 2012). If we fail to reject the null hypothesis the underlying series is stationary. Additionally, we use a parametric test to evaluate stationarity: the Dickey-Fuller test. This test is applied to the entire original series.

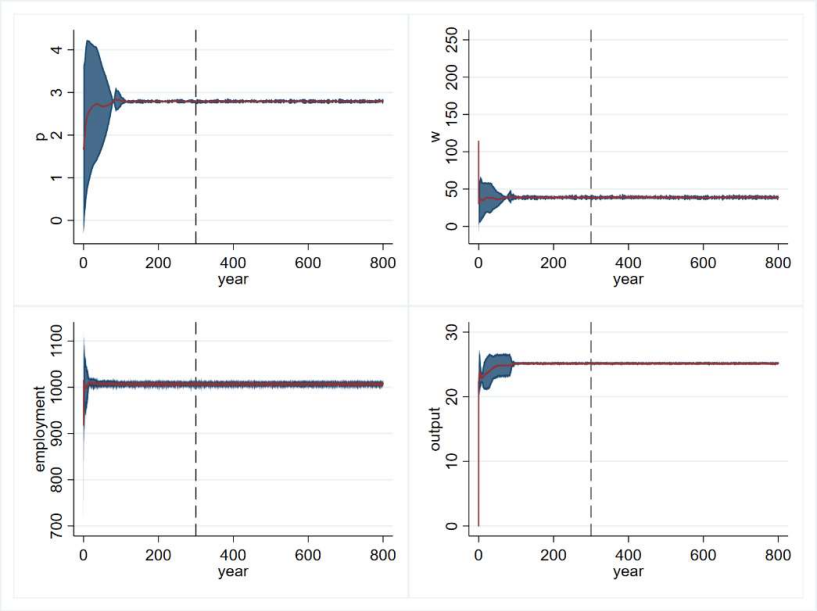
Ergodicity

To check ergodicity, we use the Runs Test again. On this occasion, we use the two series for the same variable that were obtained with different random seeds. More specifically, we take the two windows series for the same variable and combine them, that is, we create a vector of 192 observations with the means of each window. Next, we sort the vector in ascending order. Lastly, we create a dummy version of the vector assigning a value of 1 or 0 if the window corresponds to the first or

second series, respectively. We reject the null-hypothesis of ergodicity if the Z-value for the number of runs is too low (left-one tailed test), that is, if there are important bunches of zeros or ones in some regions of the combined series, indicating the two series come from different distributions.

Results

Figure A.3.1 Mean and 95 percent CI for the main aggregates of the model



Source: Authors' own calculations based on ten simulation runs of the model. The vertical dotted line represents the end of the burn-in period. Output in thousands.

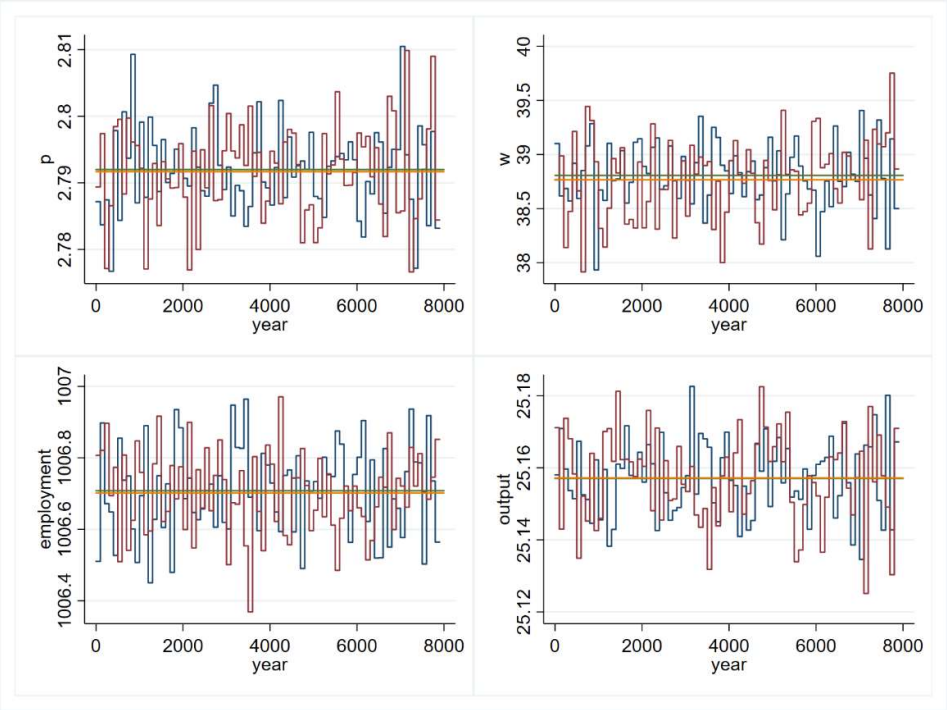
Figure A.3.1 presents series for the mean and 95 percent confidence interval for the four variables – average price, average wage, total employment, and total output in the economy – resulting from ten simulation runs of the model with different initial seeds.[42] We observe that following the wide range of initial values for the four variables these variables converge to specific values in about 200 years. By the end of the burn-in period (i.e. 300 years) all variables are near their statistical equilibrium. These results suggest that the model is ergodic and that the burn-in period is necessary for erasing the effect of initial values for control variables.

Figure A.3.2 presents the two-window series for the average price, average wage, total employment and total output in the economy. The horizontal line represents the overall mean of the underlying series. For the four variables the overall mean roughly coincides between the two series, indicating

[42] We initialize with random values (anchored to the random seed) the following variables: p_f, w_f, i_f, d_f.

Ergodicity for the series. In fact, we find that all the four variables are stationary using both the Runs and Dickey-Fuller Tests. The series are also Ergodic using the Runs Test.

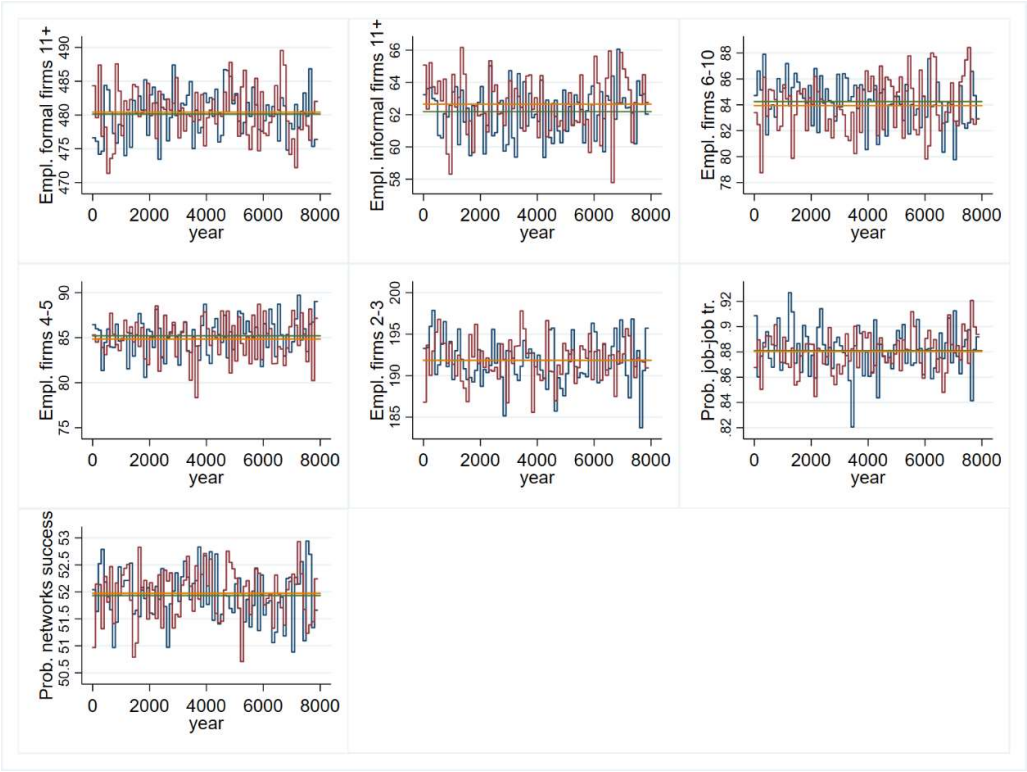
Figure A.3.2 Window series for the main aggregates of the model



Source: Authors' own calculations.

Figure A.3.3 presents the two-window series for the moments used for estimation: total employment in firms with workers in the intervals 2-3,4-5,6-10, total employment in firms with 11 workers or more in the formal or informal sectors; probability of obtaining a job using job contact networks and probability of job-to-job transition. For the seven variables, the overall mean of each one of the two series coming from different random seed are similar. The only exception being total employment in large informal firms, where the means are somewhat different. Nevertheless, almost all moments are stationary using both tests, with the exception of one of the job-to-job transition series for which we reject the null for the Runs Test (the same series is stationary under the Dickey Fuller test).

Figure A.3.3 Window series for the moments used for estimation

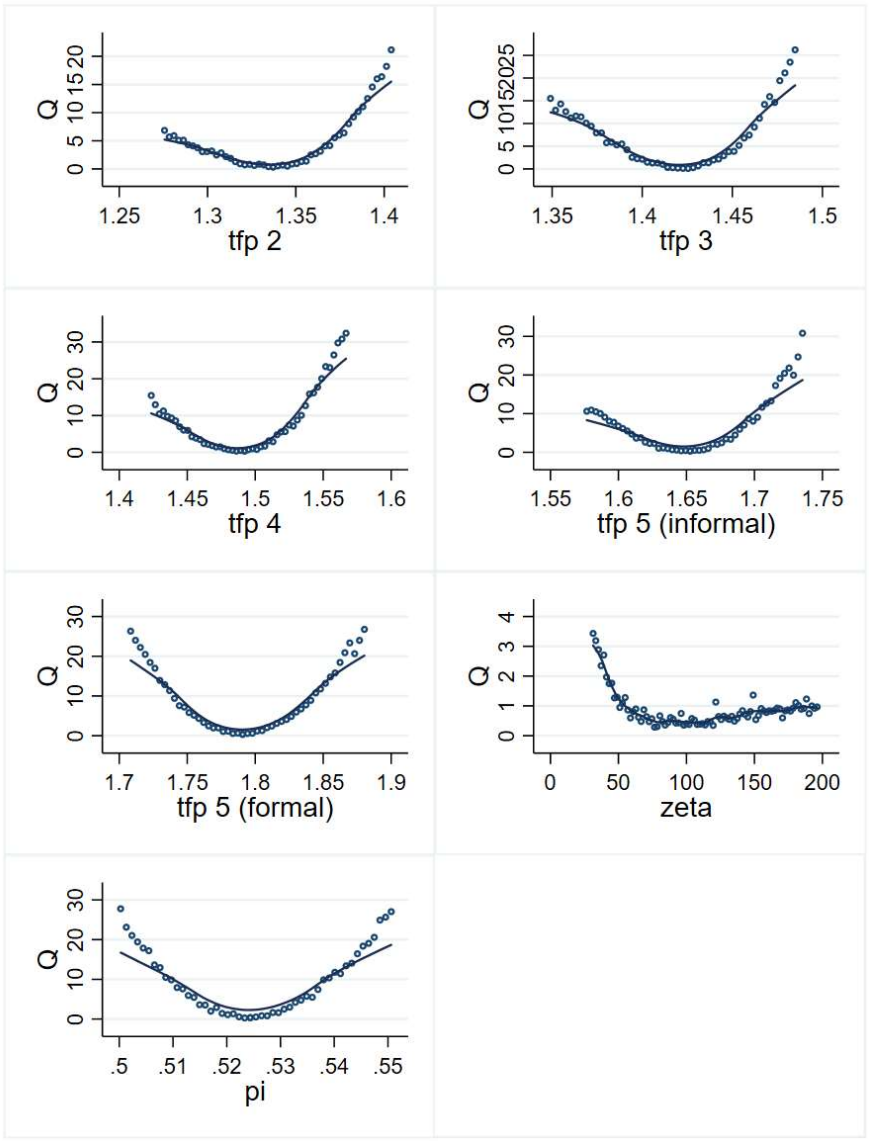


Source: Authors' own calculations.

A.3.2 Sensitivity of the estimated parameters

Figure A.3.4 presents the value of the objective function Q in Equation 7, in the vicinity of the parameter estimates. We observe that, ceteris paribus, small changes in one of the parameters dramatically increase the value of the Q function. The only exception seems to be $\overline{\zeta}$ which seems to be imprecisely estimated. This graphical inspection indicates that the parameters estimated are identified from the moments used.

Figure A.3.4 Evaluation of parameter estimates



Source: Authors' own calculations. Local polynomial smoothing superposed.

Conclusion

Informality has been a recurring negative feature of most developing economies for a long time. As it was discussed throughout this thesis, informality represents one of the greatest obstacles to reducing poverty and inequality, to increasing revenue, and to bringing citizens the public goods they deserve. This thesis introduced microsimulation as a novel methodology to analyse informality in developing countries. Such an approach has the advantage of exploiting the heterogeneity of the population captured in household survey data, which is nowadays available in most countries around the globe. This methodology has the potential to improve our understanding behind the persistence of informality and the type of policies that could reduce the size of the informal sector while increasing workers' wellbeing.

As a motivation for the potential of the proposed methodology, throughout the chapters of this thesis, we carried out several simulation exercises using different types of microsimulation techniques: static, behavioural, and dynamic. On these exercises we explored the effects of variables such as taxes, social insurance contributions, education and job contact networks on the segmentation of labour markets in a developing economy such as Colombia. We also shifted the focus from labour demand, as it is common in the informality literature, to the determinants of the supply of labour in the formal and informal sectors.

In the first chapter we introduced the use of tax-benefit models to empirically assess the financial disincentives to supply formal work at the individual level and their consequences at aggregate level. Given that the formal-informal divide usually includes an important earnings gap, we econometrically estimated the potential income of informal workers upon entry to formal employment. We find that, in the event of formalizing informal workers, formalization tax rates, defined as the proportion of the change in earnings that is taxed away upon formalization, are high for Colombia, especially given the requirement for employees and self-employed workers to contribute to social insurance at least based on a minimum wage. On average, around 92 percent of workers' additional earnings in formality would be taxed away in the form of increased taxes and social insurance contributions in Colombia. At the aggregate level formalizing the entire economy implies that around 50 percent of the inequality and poverty gains (resulting from earnings improvements after

a hypothetical transition to the formal sector) are lost because social insurance contributions reduce disposable income. Unsurprisingly, the social security system would see revenues increase by as much as 71 percent in the event of this across-the-board formalization of workers. Although this far-reaching formalization exercise will necessarily have second order effects, our results shed light on the burden the tax system places on the economies of developing countries and how formalization policies have to consider labour supply incentives.

If monetary incentives are positive but low, what could incentivise workers to transit to the formal sector? And more importantly, do they have the possibility of doing so? In the second chapter we estimated several models of labour supply, some of them including demand side restrictions to move the discussion from accounting to behavioural responses. We argue that there are unexplored possibilities of using the cross-sectional household microdata available in countries such as Colombia to simulate labour supply responses in informal markets. To better motivate the potential of counterfactual simulations using labour supply models, we based the main exercise in the chapter on a comprehensive labour supply model that includes sectoral choice (formal-informal) on top of demand side restrictions. Our simulations indicate that neither reducing the tax burden nor increasing education would trigger an important move of informal workers to the formal sector.

In our last chapter we extend an existing agent-based model to study the effect of direct and indirect (using contact networks) job search in an economy with an important informal sector. We estimate most of the technology and job-search parameters of the model for the Colombian economy. We argue that this modelling framework could prove useful when dealing with complex phenomena, where mathematical solutions are not available, such as the endogenous creation and destruction of contact networks. Although the use of contacts for job search have been found to reduce the quality of jobs for disadvantaged workers in the literature reviewed, this negative effect does not seem to apply to informal workers in our model. The available data indicates that the observed probability of using job contacts is around 40 percent, implying that, despite the high degree of homophily of contact networks found by our exploratory model (on average more than 70 percent of contacts are in the same sector), workers are able to obtain better paid jobs in the formal sector, benefiting from the positive externalities that keeping a contact network offers.

Although the three chapters presented a basic version of different microsimulation models, there are important avenues of future research to exploit the potential of this technique to study informality. For instance, the static tax-benefit microsimulation model could include labour market responses to account for potential changes in wages and employment that will necessarily alter the static results obtained. An improved structural labour supply model could include couple's decisions and take into account self-employment, these two features being of importance in the household supply of formal work decision in developing economies. Lastly, the setup of the job contact network in the macroeconomic ABM model could be improved to better recreate the formation and destruction of links and the use of other direct search mechanisms such as the internet.

From a policy point of view, this thesis indicates that governments should accommodate the social insurance system to the reality of labour activities in developing economies. Previous research has highlighted the role of payroll taxes on the formal-informal divide exclusively from a demand point of view. Our findings highlight similar concerns must be borne in mind in the case of formal labour supply. The social insurance system is not the only thing to worry about. Our findings also indicate that there are important barriers for currently informal workers to offer their abilities in the formal sector. Despite the fact that tertiary education, a variable potentially under government's control, is the only observed variable that has an important effect moving workers to the formal sector, there are other unobserved variables that prevent a higher availability of formal jobs for informal workers. Lastly, one of the variables that should not worry policy makers much is the use of job contacts for job search. Our results indicate that the current propensity of use of contacts allows for an important dissemination of job availability information among networks of contacts. However, the effect of contacts on referral hiring (not captured by our model) remains to be analysed.

■