Centro de Estudios®
Espinosa Yglesias
PROMOVEMOS LA IGUALDAD
DE OPORTUNIDADES

Social Mobility, Economic Growth and Socioeconomic Inequality in an Economy without Informality and with Social Protection

Autores:

Florian Chávez-Juárez
LNPP - CIDE

Raquel Y. Badillo Salas
LNPP - CIDE

Victoria Hernández Sistos
LNPP - CIDE

Documento de trabajo no.

04/2017

Centro auspiciado por: ESRU Fundación Espinosa Rugarcía

Social Mobility, Economic Growth and Socioeconomic Inequality in an Economy without Informality and with Social Protection[1]

Florian Chávez-Juárez
Raquel Yunoen Badillo Salas
Victoria Hernández Sistos

Julio 2017

Abstract

Mexico is characterised by low economic growth, high income inequality and low intergenerational mobility. These outcomes are likely to be linked to each other. In this study we develop an agent-based model allowing us to study the effects of a radical change in the Mexican Social Security System on inequality, social mobility and economic growth. In particular, we study the effect of moving from the currently implemented dual social security system to a universal system paid through taxes rather than contributions of formal workers. Our model includes traditional elements such as families optimising their utility and firms optimising their profits, but also a series of other processes such as education dependent fertility, assortative mating and search frictions in the labour market. Our baseline model reproduces the actual situation in the Mexican economy quite reasonably and allows us to carry out the simulation of policy changes. The results of this simulation exercise show relatively modest effects in terms of inequality and social mobility. GDP growth is substantially higher under the new policy. This GDP gain is essentially due to an increased proportion of formal firms once the contributions to social security are dropped.

Keywords: inequality, social mobility, economic growth, social security, Mexico, agent-based model.
JEL-Classification: C63, D63, H20, H52, H55, I24, I30, J20, J62.

.

[1] This study has been commissioned and partially funded by the Centro de Estudios Espinosa Yglesias (CEEY). We would like to thank CEEY and in particular Marcelo Delajara for their support, Diana Flores, Lilian Medrano and Gonzalo Ares for their research assistance during the first phase of the project and Cristina Galíndez for her administrative support. The presented results in this study are based on work in progress. All errors are ours.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Mexico, like most countries in Latin America, is characterised by large economic inequalities and very low social mobility. In terms of intergenerational correlations in years of education, Latin American Countries display substantially larger values than countries on other continents. Among the Latin American Countries, Mexico is among the countries with the highest correlations (Hertz et al., 2007). Social mobility is closely linked to economic inequality. With a few exceptions[1], most studies find a negative relationship between social mobility and economic inequality (Erikson and Goldthorpe, 1991; Ozdural, 1993; Becker and Tomes, 1986; Björklund and Jäntti, 1997; Corak, 2013; Torche, 2014; Andrews and Leigh, 2009)

At the same time, Mexico has experienced long periods of very modest economic growth. According to data from the World Bank the annual growth rate of the GDP per capita in current US$ over the last 10 years was about 1.3% in Mexico, which is substantially lower than other countries in the region such as Brazil (6.1%), Bolivia (11.5%) or Chile (5.6%) (World Bank, 2016).

Both phenomena, low growth rates and low social mobility (or high economic inequality), are likely to be related to each other. For instance, OECD (2015) highlight the negative relationship between income inequality and economic growth in OECD countries.

The goal of this study is to analyse the relationship between these three phenomena and to see whether changes in the social security system can help improve the situation. In particular, the main research question is whether a change in the Social Security System - from the currently dual system with a contributory and a non-contributory system to a universal system - can reduce inequality, increase social mobility and increase economic growth as a consequence. The hypothesis is that such a change in the social security system would mainly benefit the poor and would therefore decrease inequality. Lower inequality should then generate higher social mobility and eventually higher economic growth.

Answering such a big research question is very challenging and complex, because many socioeconomic processes play an important role. In this study we aim at providing a first attempt of an answer. We do so by developing a theoretical model that is grounded in empirical evidence and a wide range of previous work on the topics. The model must be able to take into account multiple socioeconomic phenomena and adjust sufficiently close to the actual Mexican situation.

We have two specific goals in this study. First, we aim at producing a model that is sufficiently close to the Mexican reality and reproduces a series of key statistics appropriately. Second, we perform a simulation exercise of

[1] Checchi et al. (1996) point to a positive relationship when comparing the US with Southern European Countries.

a specific policy proposal aiming at introducing a universal social security system in Mexico.

To achieve these goals, we base our model on the existing literature and as much as possible on empirical evidence. With regard to the literature, we rely on two main references. On the one hand Antón et al. (2012) who develop a model for Mexico in which they focus on the firm side and deal with questions of formality, social security and growth. On the other hand, we follow Chávez-Juárez (2015) for phenomena related to the family investment in education and social mobility.

The model is built around individuals, families, firms and the government. We use a four sector economy and adjust the model as much as possible to the Mexican system. The education, tax and current social security systems are directly modelled according to the Mexican legislation. In addition to rather standard elements such as a utility maximisation for families and a profit maximisation for firms, we also include processes such as assortative mating, education dependent fertility and matching frictions in the labour market.

In order to build such a complex model, we use innovative agent-based modelling techniques. These techniques are particularly well suited for this study for a number of reasons. First, agent-based models allow us to include the aforementioned sub-processes and mechanisms that are likely to matter for the research question. Second, agent-based models allow us to model closer to the reality of a particular country. In this study we implement the Mexican tax and Social security system quite closely to reality. Moreover, we initiate the model with survey data from the Mexican Family Life Survey (MxFLS). Thirdly, agent-based models allow us to analyse not only a long-term equilibrium, but also short-run effects of any policy change. These short-run effect can be different from the long-run outcomes. Understanding these differences is very important in terms of public policy, in particular in a country where the administration is elected every six years without the possibility of renewal. Hence, reforms with short-term adverse effects and long-term benefits might be difficult to implement.

While these advantages of agent-based models are key to our study, the technique also comes at some cost. For instance, we are not able to provide analytical solutions and there is a certain risk for the model to become too complex. This complexity might then result in a reduced understanding of what is happening in the model. To avoid creating a black box, we simplify a number of processes, such as the education and health sector for instance. It is very important to underline the fact that the model we present in this study is a first attempt to approach the topic and to model the economic situation in Mexico. Many modelling details will require further research in order to be refined and provide more accurate results. In this respect, we see this study as a first iteration of the iterative modelling approach described in Chávez-Juárez (2016). This first model answers some question and raises new ones, which can then be addresses in other studies, both empirically and by adapting the proposed model.

The results of our simulation study shows that the change from the dual to a universal social security system has only very modest effects on social mobility and inequality. While inequality slightly decreases, we do not find any change in relatively social mobility. In contrast, we do find some positive effect on absolute intergenerational social mobility and on economic growth. The effect on absolute social mobility seems to be due to the change in the social security system, while the effects on GDP growth are more likely to stem from the accompanying tax reforms. The clearest effect we find is with respect to the proportion of formal firms, which increases sharply after the change in the social security system. This important change is due to the elimination of the social security contributions which are with roughly 20% quite high, especially for low wages.

We will start with a short literature review in section 2, followed by the presentation of the core elements of the model in section 3.1. A complete explanation of the model aiming at increasing its reproducibility is presented in the form of the *Overview, Design concepts and Details (ODD)* protocol in Appendix A. The results are presented in two steps, first we present the baseline model in section 4.1 and then the effects of the change in the social security system in section 4.2. Section 5 then concludes the study by highlighting the most important point and discussing the future steps to be taken. In addition to the detailed explanation of the model, the appendix also includes additional information on agent-based models, some sensitivity analyses and an explanation on the calibration of the model.

Chapter 2

Literature review and background information

The model we develop in this study is very extensive in terms of phenomena and processes we include. As a consequence, discussing the literature of each of the processes in detail would be beyond the scope of this article. We therefore focus our literature review on the most important contributions and on articles that directly contribute to our model. Two references using Mexican data are of particular interest for this study. On the one hand, the model developed in Chávez-Juárez (2015) uses the same technique as our model and focuses on intergenerational mobility, investment in education and the family decisions. On the other hand, Antón et al. (2012) focus on the decisions taken by firms and discuss important issues of the tax and social security system. Hence, these two references complement each other almost perfectly for the sake of this study and therefore form the starting point of this model. Both references include an extensive literature review of their respective main issues. In this literature review we discuss some key elements of these strands of literature, but we are not able to discuss all the details.

We start our literature review by discussing the key processes for social mobility and present them in a chronological order from the point of view of a child. We start with processes taking place very early in life and then move to what happens later. Afterwards we will discuss the literature on which the model presented in Antón et al. (2012) is based on.

2.1 Assortative mating

Important processes for social mobility take place well before birth. The marriage market is characterised by a non-random mating, where individuals with similar characteristics are more likely to meet. Becker (1973) provides a theoretical rationale for this phenomenon of assortative mating. Ermisch et al. (2006) use German and British data and finds that between 40% and 50% of the covariance the income of two generations can be attributed to assortative mating. Thiessen and Gregg (1980), Wolf and Figueredo (2011) and van Leeuwen et al. (2008) discuss assortative mating from an evolutionary and biological perspective.

Using data from Mexico, Wendelspiess Chávez Juárez (2015) finds spousal correlations of 0.4 for the IQ and of 0.65 for years of education. As a consequence, it is likely to have both parents with similar levels of education and no regression to the mean takes place. Given that high parental education is an important advantage in life, children have either a double advantage or a double disadvantage. This advantage manifests itself mostly through the resulting intergenerational link in education.

2.2 Socioeconomic gradient in fertility

A second important phenomenon for social mobility taking place before or at birth is the education dependent fertility rate (Chávez-Juárez, 2015). It is well documented that more educated parents tend to have fewer children. Using data from Mexico, Chávez-Juárez (2015) finds that very little educated women have on average almost 5 children, while university graduates have only 2 children on average. This phenomenon is important for two reasons. First, families with little educated parents tend to have lower incomes and in addition, they have to use these resources for more children. As a consequence, the per capita investment in education is likely to be substantially lower in families with poorly educated parents. According to the model proposed by Chávez-Juárez (2015), the education dependent fertility account for up to 10% of the intergenerational correlation in education with the mother.

2.3 Human capital accumulation

The two already discussed phenomena directly matter for the human capital accumulation of the children. Education is a key element for both economic growth and social mobility. Education directly affects labour productivity and innovation, two key factors for economic growth. In terms of social mobility, we observe a strong intergenerational correlation in terms of years of education (Hertz et al., 2007). This transmission starts very early, because at least some parts of cognitive ability are genetically transmitted from one generation to the next (Björklund et al., 2010; Anger and Heineck, 2010; Black et al., 2009). Parents with higher cognitive abilities tend to have higher incomes and more education. By transmitting these abilities to the next generation, the children are more likely to have good outcomes in terms of education and income. Consequently, we end up observing intergenerational correlations both in education and income. However, educational correlations across generations are not only due to biological factors. Another very important element is the possibility and willingness of parents to invest in the education of their children. Most models of social mobility use this process as key explanatory factor. For instance, Maoz and Moav (1999) include liquidity constraints in their model to explain why low income families invest less in the education of children. Similar approaches are taken by Galor and Zeira (1993) and Becker and Tomes (1986). This phenomenon is reinforced by the education dependent fertility discussed in the previous section. Empirically, various studies have concluded that this economic channel is important in explaining social mobility. Carneiro and Heckman (2002) find that in the US only about 8% of students have short term credit constraints. However, they argue that the long term economic conditions of the family appear to matter more for the intergenerational transmission of education. Alfonso (2009) confirms this relatively more important role of long term economic conditions for four Latin American Countries. Wendelspiess Chávez Juárez (2015) compares the importance of different transmission channel in Mexico and finds the economic channel to be the single most important one. He further decomposes the effect in long- and short-term effects and also finds a relatively more important role of the long-run economic situation of parents.

All the elements discussed up to this point, namely assortative mating, genetic transmission of cognitive ability and the income gradient in education investment build the core elements of an agent-based model developed in Chávez-Juárez (2015). Chávez-Juárez (2015) aimed at analysing the effects of cash transfer programs on educational mobility. As a consequence, his model does not look at phenomena beyond the human capital accumulation. Given the goal of our project and the particular interest in the social security system and economic growth, the model proposed by Chávez-Juárez (2015) must be complemented in various ways. We will now discuss these additional phenomena that are mostly discussed in Antón et al. (2012).

2.4 Social security system and informality

The social security system is essentially absent in Chávez-Juárez (2016). However, it might have various implications both for social mobility and economic growth. Economic shocks due to urgent medical conditions of family members or unemployment of the breadwinner for instance, will generally affect poor households more. In particular, such shocks can negatively affect the education attainment of children if they have to drop out of school for instance (Woldehanna and Hagos, 2015; Duryea et al., 2007; Bound and Turner, 2011). The importance of such economic shocks in general is directly linked to the social protection in a given country. A strongly developed social security system might help reduce the negative consequences of health shock on education. Such a protection over-proportionally helps families at the lower end of the socio-economic distribution because wealthier families can more easily cope with shocks even without social protection. Hence, when looking at the link between economic shocks and social mobility, it is of paramount importance to consider also the social security system.

Looking at the Mexican social security system more closely brings us directly to another important topic discussed in Antón et al. (2012) that should be added to Chávez-Juárez (2016): informality. In fact, the Mexican social security system is a dual system, one for formal workers with large benefits and complete coverage (*IMSS* and *ISSSTE*) and one for informal workers with a limited safety net (*Seguro popular*). The *Seguro Popular* has a substantially lower coverage of around 250 medical treatments as compared to the full coverage of the contributory social security system for the formal workers. As a consequence of this dual system, the social security system itself can be a source of low social mobility in case low-income families are more likely to operate in the informal market where social security is lower and therefore economic shocks hit harder.

Of course, the phenomenon of informality is not only linked to the concept of social mobility but also - and probably even more - to economic growth. For the purpose of our model, the dual economy plays a role in two processes: firms have to decide whether they operate in the formal or in the informal marked and workers have to take a similar decision.

Informality has been discussed in very different ways in the literature, by focussing either on firms' choice, workers' choice or a total segmentation of the markets.

Let us first discuss the approach where formality is mainly linked to the firms' choice. This approach has been used in Antón et al. (2012) and will also be the starting point for our model. The approach includes three main channels: regulation entry, credit constraints and tax compliance. For example, in the first channel we find some influential work such as Djankov et al. (2002) that argues firms face significant entry costs to be able to operate formally, these costs are in form of registration and licenses fees. In the second channel some authors such as Straub (2005) argue that some services that improve the productivity of the firms are restricted to the formal sector. This is because the informal sector does not register their activities and it is difficult for banks to monitor them. Finally, in the third approach, firms choose formality or informality based on tax compliance. In this approach we find some authors such as Antón et al. (2012). Firms can be formal with certain cost of entry or informal and illegal with certain probability to be caught by the authority. Incomplete tax enforcement distorts decisions in allocation of resources.

In the second approach, we find some authors such Maloney (2004) arguing that informality is a worker decision.

Some workers prefer informal jobs because they are able to find substitutes for the protection or services offered by formal institutions or are willing to trade these formal benefits in exchange of other amenities in the informal sector such as time flexibility, greater independence or less pressure environment. Maloney (2004) argues that informal workers choose informality because entrepreneurial desire to create their own business or because skills obsolescence.

Finally, a last approach of market segmentation was an idea implemented by Lewis (1954) and after formalised by Harris and Todaro (1970). Wages in the formal sector are set exogenously and higher than in the informal sector. For this reason, informal workers are always trying to enter to formal sectors but these formal jobs are restricted to a limited quantity. The main implication of this model is that wages set above of market equilibria in formal sector will produce unemployment and less production in both informal and formal sectors. However, this approach considers a segmentation between the sectors, with low or no possibility of moving from one sector to the other.

As previously mentioned, we will base our model on the first approach, where firms decide whether to operate formally paying taxes and social security contributions or not. The approach does not include a mechanism for the labour market, which is of course of paramount importance for the development of our model.

2.5 Labour market

Models with search and matching frictions deal with the labour market and formality at the same time. In this kind of models, the formal sector suffers of market rigidities: workers and employers meet each other only through available job offers, while the informal sector is completely competitive, without entry barriers for workers nor for employers (see Albrecht et al. (2009); Zenou (2008)). The main implication of this assumption is that in the formal sector, the wage is determined by a bargaining between workers and firms. Albrecht et al. (2009) allows for heterogeneity in workers' skills and find that on average formal workers are more productive than their informal-sector counterparts.

This last approach with a bargaining in at least some of the sectors is another important element for our study. Social mobility creates a mismatch between ability and education due to the aforementioned mechanisms. This mismatch is likely to create suboptimal matching in the labour market as well, given that firms generally can only observe education, but not ability.

The literature has proposed several ways in which firms search and hire workers[1]. We can broadly group the approaches into two main focuses. The first refers to a random process, where workers and firms stochastically meet. In this focus we can find some authors such as Diamond (1982) and Zenou (2008). They argue that the matching process is similar as if firms were urns and workers were balls. If all workers and firms are ex ante identical and if only one worker can occupy each work an uncoordinated application process will lead to overcrowding in some jobs and no applications in others.

The second approach refers to a meeting probability based on heterogeneous characteristics of the workers and firms. Authors such as Basu et al. (2015) argue that not every worker knows about all market vacancies. They assume that not all job seekers receive the full set of offers. Instead firm and job seeker meet each other with a probability that depends on their skill type (high or low), expected job offers and the minimum wage in the economy. In our context, an additional reason for heterogeneous access to job offers is the social status and social networks. We will focus on this approach because some heterogeneity of workers might be very important in explaining their access to the formal labour market.

[1]Petrongolo and Pissarides (2001) provide a good overview and generalisation of a number of approaches and group them into six categories.

2.6 Capital market and investment by families

A last important element that should be added in this study is the capital market and capital ownership. In seminal contributions such as Becker (1975), Loury (1981) and Galor and Zeira (1993), capital plays a crucial role in explaining intergenerational persistence of income, wealth and education. Richer families are able to hold financial assets which affect social mobility in at least three ways. First, as already mentioned before, financial assets can help reduce the effect of economic shocks and therefore in the absence of a social safety net, richer families are substantially less vulnerable to shocks than poorer families. Second, families with higher wealth can invest more in the education of their offspring, which will result in higher earnings in the long run. Finally, capital stocks generate capital income in addition to labour income. This directly increases the income inequality and therefore the capabilities to invest in the education of the next generation, even without using the wealth stock itself.

2.7 The Mexican context

In addition to the above general discussion, it is important to understand the Mexican context and to discuss how the current policy mechanisms might affect social mobility. We first discuss the social security system, focusing on the health sector and then discuss the tax system along with already proposed reforms.

2.7.1 The Mexican social security system

The Mexican social security system is characterised by a dual system where formal workers have access to a contributory social security system (IMSS or ISSSTE), while informal workers can only have access to the non-contributory health system *Seguro Popular*, which covers substantially less medical conditions. Social security essentially refers to the provision of health care services and some compensation payments (e.g. maternity leave in the contributory system). Unemployment insurance is not available.

There are major differences between the contributory and the non-contributory system in terms of financing and coverage. With respect to financing, in the contributory system workers pay a share of their gross salary, while the non-contributory system is almost exclusively funded by the federal government through income taxes. Beneficiaries have to pay only a small fee per family that depends on their economic situation. The fee is very low[2] and therefore we simplify the discussion by assuming that health care is for free.

In terms of coverage the contributory system has full coverage of all medical conditions, while the non-contributory system is limited to slightly more than 250 medical treatments, including preventive care, general practitioner services, specialist services, emergencies and some surgery treatments (Seguro Popular, 2016).

2.7.2 Tax collection and proposed reforms

Mexico has one of the lowest tax collection in the world. According with Campos Vázquez et al. (2014), the Mexican tax structure has not been effective in reducing the inequality; therefore, the social mobility in Mexico is very low. In recent years, there have been different proposals of fiscal reforms that could have an effect in social mobility. Two popular proposal involve an increase of the value added tax and an increase of the income tax for the richest respectively.

[2] Families in the first four income deciles are waived from the fee, those in the fifth decile pay the equivalent of 112 USD a year and the richest families pay a maximum of 615 USD (Secretaría de Salud, 2016)

With respect to changes in the value-added-tax various proposals have been made. Currently most products are taxed at 16%, while food and medicines are taxed at a reduced rate which is currently set to 0%. Some proposals target an increase of the general tax rate of 16% to a higher level (not very popular), while other proposals would rather generalise VAT to all products by increasing the reduced rate (Antón et al., 2012). Nevertheless, this approach has been criticised because an increase of the VAT (especially on foods and medicines) could be highly regressive. Antón et al. (2012) argue that regressivity can be avoided by removing all taxes on formal employment and subsidies to informal employment. In this way the net income would be bigger and every citizen would have access to universal social security, regardless of their employment status (formal or informal). Of course, this proposal goes far beyond a simple tax reform, as it would also completely restructure the social security system. In our policy analysis we simulate a version of this proposal.

The set of proposals aims at changing the income tax rate for the wealthiest people. According with Campos Vázquez et al. (2014), the share of total income of the richest 1% of individuals in Mexico is 21.3 %. If we compare it with other countries, the richest people in Mexico have one of the highest shares of total income Campos Vázquez et al. (2014). Based on this data, Campos Vázquez et al. (2014) found, the marginal rate of income tax has to be between 40 and 60%, which is clearly above the current rate. This increase would be reflected in a growth of at least 7% of the direct tax revenues. In a joint article the *Economic Commission for Latin America and the Caribbean* and *Oxfam* recommend increasing the income tax rate for the top earners (CEPAL and OXFAM, 2016).

Chapter 3

The model

In this section we describe the cornerstones of our agent-based model and focus on the most relevant aspects. In addition to this discussion, we present all the details of the model in the *Overview, Design concepts and Details (ODD)* protocol in the appendix A (Grimm et al., 2006, 2010; Polhill, 2013). The ODD aims at increasing the reproducibility of agent-based models and allows the reader to understand the details of the modelling approach. A general discussion on agent-based models in general is proposed in appendix E.

3.1 The model at a glance

3.1.1 Key actors and their relationships

The goal of our model is to discuss the effects of a universal social security, as opposed to the currently implemented dual system, on intergenerational social mobility, inequality and economic growth. The working hypothesis is to find a positive relationship between social mobility and economic growth (Maoz and Moav, 1999), i.e. if social mobility is low, economic growth is small. We therefore expect a universal social insurance to have a positive effect on social mobility and consequently on economic growth.

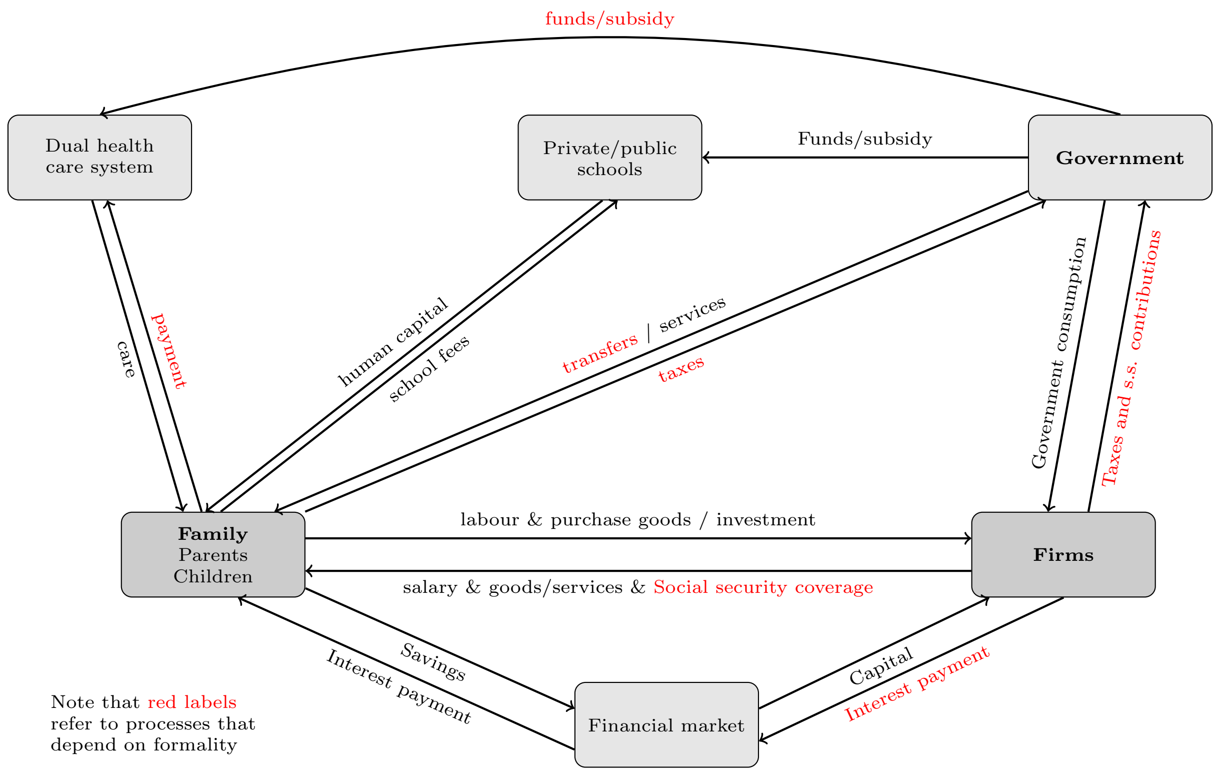
In order to simultaneously study social mobility, inequality and economic growth, we have to model both families and firms. These two entities build the core of our model, but we also include the government, schools and the health sector. While the model we propose in this study is completely new and built from scratch, it is inspired by previous models of the different sub-topics. With respect to social mobility and education, we take many elements from Chávez-Juárez (2015). In terms of the structure of the economy and the dual social security system, our model is largely based on ideas presented in Antón et al. (2012). In addition to these two main references, we use concepts from various fields in economics. For instance, the family decision making process is governed by a utility maximisation which follows to some extent a Beckerian approach (Becker, 2009).

Schematically, we can represent our model as shown in figure 3.1.

Agents are represented in grey boxes; the most important agents are highlighted with bold text. The arrows between agents refer to processes and/or relationships among agents. Red labels refer to processes and relationships that depend on the formality status of firms and workers.

Families and **firms** are the key actors in our model. Families interact with all other agent types, especially with firms and the government. The relationships with firms are multiple as families are customers by purchasing

Figure 3.1: Schematical representation of the model



goods and services, workers by supplying labour and investors by offering capital either through direct investment or through the financial market. The interaction of families with the government is essentially a financial interaction, where families pay taxes (income and value added) and received under some circumstances transfers. With respect to the dual health sector, families have different levels of access to the system depending on the formality status of the firms they work for. Family members of formal workers have access to the contributory social security system which includes mostly free of charge health care services.

The interaction of firms with the government directly depends on the formality status of the firm. Formal firms pay both taxes and social security contributions to the government. Informal firms do not pay taxes except for the value added tax on input products.

The financial market is implemented in an extremely simple way by exogenously defining both the interest rates on loans to firms and on savings. Families can only save but not borrow on the financial market.

Finally, it is important to notice that we are in a small open economy where prices and interest rates are exogenously set. However, in order to have a certain link between the demand and the supply of goods, we endogenously adapt prices when the differences become too large. The details of this process are explained in the ODD (see A.3.3.5.3).

3.1.2 Time frame and order or processes

The time unit in our model is one year and in each period a series of actions take place. The following list provides an overview of the main actions and subsequently we will discuss some details:

1. Couples **procreate** with a certain probability that depends on the education and age of the woman.

2. Nature produces **health shocks** for each individual. The likelihood and intensity of the shocks depend on individuals' characteristics.
3. Enrolled children either **pass** or not the school year.
4. Single individuals **mate** with a certain probability.
5. **Firms optimise their labour and capital structure** based on current prices in the market. If this involves hiring workers, job offers are created and sent to the market.
6. All individuals that are no longer at school and attained the minimum legal age to work compute their reservation wage and **apply to job offers** with at least this salary.
7. **Firms hire** among all the candidates who applied to their offers.
8. **Firms** adapt their capital and input quantities to the actual outcome of the hiring process and **produce** their goods and pay the workers.
9. **Families make their consumption, health investment and education investment decisions** based on their disposable income and their utility function.
10. The **government receives taxes and spends the money** in social security and in government consumption.

Once all these and a few secondary steps are completed, the next period starts. We will now discuss in more details some of the processes presented in the list. In the interest of clarity, we focus on the most important processes and present less relevant processes only in the appendix A.

3.2 Families

Families represent the most important agent type in our model, because they are the main consumers, supplier of the labour force, investors in firms and are directly responsible for key phenomena such as social mobility.

Families take a series of important decision, some of which are modelled through an optimisation process, while other decisions are implemented in a more passive[1] way.

3.2.1 Consumption and investment decision

The decision on how to use the disposable income is probably the most important decision of the family and drives many of the results of the model. We base this decision on the general idea of the Beckerian approach (Becker, 1973), where families optimise a utility function and no intra-household bargaining takes place. The disposable income can be used for consumption, savings and investment in both health care and education. We assume the following Cobb-Douglas utility function:

$$U(c_t, H_t, E[y_c], E[m_{t+1}]) = c_t^{\alpha_c} \times H_t^{\alpha_h} \times E[y_c]^{\alpha_y} \times E[m_{t+1}]^{\alpha_m} \tag{3.1}$$

where c_t is the per capita family consumption in period t, H_t is a statistic capturing the average health status of the family members, $E[y_c]$ is the expected income of the children based on the current income structure and $E[m_{t+1}]$ is the expected disposable income in period $t + 1$.

[1]With 'passive' we refer to simpler behavioural rules that do not imply an optimisation process.

The idea behind this utility function is that families care about consumption, health and education. Health enters the utility function through the average health stock of the family members. In case all members are in perfect health and nobody suffered a health shock in this period, H_t is equal to unity and no investment in health can increase this statistic. In contrast, if at least one of the family members suffered a health shock, H_t can be influenced by the family through investment in health. As we will discuss later, depending on the health system the family has access to, the same amount of money translates into more or less health improvements.

Contrary to Chávez-Juárez (2015) who includes the offspring's years of education in the utility function, we rather use the expected future income of the children[2]. Again, we use the average income of all children and compute the expected values based on the current average incomes by education level.

Finally, we introduce an inter-temporal notion by including the disposable income of the next period in the utility function. This disposable income is basically the expected income of the next period plus any savings the family might make in period t.

Note that the education enrolment decisions are only taken at the beginning of a level, for instance once the child has finished primary education the family optimises over the possible enrolment decisions for lower secondary education. For each child three options are available: no enrolment, enrolment at a public school or enrolment at a private school.

3.2.2 Labour supply

The labour supply of the family members is implemented in a rather simple way. We assume that both parents aim at working whenever they are not yet retired. Children enter the labour market once they finished school and attained the legal age to work (we assume 12 years). All eligible individuals will then compute their reservation wage and see job offers issued by firms with a certain probability. This probability depends on their current labour status (unemployed individuals see more offers than employed), whether they have a family member in the firm and whether they were at a private or public school. Individuals then apply to all job offers where the gross salary is weakly above the reservation wage.

The reservation wage is defined as:

$$w_i^{res} = \max(w_i^{self-employed}, \tau_L E[income|education = education_i]) \tag{3.2}$$

which is the maximum between the expected income as self-employed (producing the basic product) and the average income of individuals with the same education level as individual i multiplied by a tolerance factor $\tau_L \leq 1$. This tolerance factor allows workers to accept wage offers that are slightly below the average. The labour supply through this official labour market is complemented by labour supply as independent (self-employed) for those who did not find a job. In case a family has urgent needs for income, they can also take out of school currently enrolled children and ask them to work as self-employed.

3.2.3 Procreation

While the two previous decisions are to some extent based on an optimisation, the family decision regarding procreation is implemented in a much more static way. Based on data from the *Mexican Family Life Survey*

[2]In this point we deviate from Chávez-Juárez (2015) because our wage structure is endogenous resulting from the decision of firms, while it was exogenously set in Chávez-Juárez (2015).

(MxFLS) we estimated the likelihood of having a child as a function of the age and education of the woman similar to the approach used by Chávez-Juárez (2015). In each period we use a stochastic process to simulate whether the couple will have or not a child. Note that we do not allow for more than one child per period and we ensure a stable population in the model by multiplying all probabilities by the same factor. This factor endogenously adapts over time, but does not alter the relationship between the number of children and the education level of the mother.

3.3 Firms

The structure of the economy and the types of firms in our model are largely inspired by the model in Antón et al. (2012). Similar to Antón et al. (2012) we include four different types of firms, depending on the type of product they produce. Table 3.1 provides an overview of the products and also displays whether or not they are subject to the value-added tax and which other product they need as input.

Table 3.1: Types of products/firms in the economy

Product	**Subject to VAT**	**Inputs**
Basic product	Yes (π_{VATg})	None
Intermediate 1	No/reduced (π_{VATr})	Basic product and intermediate 2
Intermediate 2	Yes (π_{VATg})	Basic product and intermediate 1
High-tech product	Yes (π_{VATg})	Both intermediate goods

We use a generic production function with specific parameters for each product. The production function can be formally written as:

$$y_p = f(K, L, y_{-p}) = K^{\beta_K} \prod_{i=0}^{4} L_e^{\beta_{Le}} \prod_{p=1}^{3} y_p^{\beta_{yp}} \tag{3.3}$$

where K is capital, L_e labour of education level e and y_p are all the other products that can be used as inputs. We assume constant returns to scale by setting $\sum \beta = 1$.

Note that L_e refers to the effective productivity of labour per educational level (none, primary, secondary, high school, university). The coefficients β all depend on the type of product, but for the sake of readability we did not add the indices.

Firms then maximise their profit by adapting L, K and Y and by choosing their formality status. We assume that informal firms can decide to become formal, while the opposite direction is not possible. The decisions are taken by optimising the profit function[3], which depends on the prices in the market, the formality status of the firm and the productive structure of the firm. Note that in our model we do not assume zero profits for firms and due to the heterogeneity of firms in terms of structure and workers we do not expect all firms to have the same level of profits.

To sum up, firms optimise over their productive structure and their formality status, while they take prices, tax rates, social security contribution rates and the risk of fines for informal firms as given.

[3]A detailed discussion can be found in the appendix A in section A.3.3.1.2.

3.4 Government

The government is modelled in a much simpler way than families and firms. Our main research question deals with an exogenous change of the social policy. Hence, our government does not feature an active optimisation behaviour. Instead, we simply model the government according to the current social security system to simulate the baseline model and then adapt its structure for the public policy analysis.

Despite this simple implementation, a few points are worth mentioning. First, we understand as government the whole public sector, which also includes the provision of health care services. In the baseline model the government manages a dual health care system. The contributory social security system is exclusively financed through the contributions, while the non-contributory health care system is financed through ordinary taxes.

The government has three types of revenues: income tax of formal workers, corporate income tax and the value added tax. All these taxes and the payment of social security contributions were modelled according to the current legal framework in Mexico.

We then implement a very simple behaviour for the government, where it first pays for the health care and pensions. The remaining money is then spent on government consumption. To achieve a certain stability in the government consumption and to model the impossibility to reduce government spending excessively from on year to the next, we assume that the annual reduction cannot exceed a certain percentage. If in one period the government has not enough resources it can contract some debt, which is then paid back in the next period[4].

3.5 Schools

Contrary to the families, firms and the government, schools are implemented in a passive form in this version of the model. This modelling decision has been taken in order to keep track of the most important issues for the phenomena we aim at analysing and not adding unnecessary complexity to the model. Future developments of the model might well include a more active form of schools[5].

We distinguish private and public schooling but do not impose any quality differences. The only differences between the two schools is a certain preference of firms for students from private schools and a slightly higher likelihood of seeing job offers for graduates of private schools. We further distinguish the notion of human capital from the notion of years of education. Each year, students accumulate a certain level of human capital. This accumulation depends on the cognitive ability of the child, his or her health status and a random term capturing unobserved heterogeneity. One unit of human capital corresponds to a year of perfect education for a child with an average IQ of 100. In order to pass the grade, a child requires to achieve a certain level of human capital, defined as a multiple ($\delta < 1$) of the years of education.

This implementation allows us to include two important elements in a simple form. First, the process of human capital accumulation is a cumulative process where a lack of accumulation in one period (e.g. due to illness) will have a long lasting effect. Second, two children with the same number of years of schooling will not necessarily have the same level of human capital.

[4]According to our analysis, this happens very rarely in the model and we never observed a government that contracts debt for more than one or two consecutive periods.

[5]The same reasoning applies to the health sector, as we will discuss afterwards.

3.6 Health sector

Similar to the education sector, the health sector is implemented in a simple and passive way. We use a dual health sector with a basic service for everybody (non-contributory health insurance inspired by the Mexican Seguro Popular) that covers only a limited number of medical conditions and a more general contributory service (inspired by the Mexican IMSS) allowing also the treatment of more complicated medical conditions. The whole sector is modelled through the out-of-pocket spending of families, which is typically higher in the basic service, because the basic services have to be complemented with paid services.

This simple implementation allows us to include the most important feature of the dual health care system, without the need of modelling the health care sector in all its complexity. The crucial point here is that for a given level of health recovery, insurees in the non-contributory health insurance will have to spend substantially more out-of-pocket than insurees in the contributory health insurance.

Despite the fact that medical services in the contributory health insurance in Mexico are free of charge, we still assume a certain level of out-of-pocket expenditures. These expenditures may involve transportation cost and some spending for minor medical conditions that do not require inpatient care.

The definition of beneficiaries of the contributory health insurance is taken from the legal framework in Mexico, where all family members of a formal worker are automatically insured.

3.7 Nature

A few processes such as fertility and health shocks are not modelled through a decision making process but rather taken as given (nature). In order to obtain realistic results, we simulate these stochastic processes based on empirical evidence. Of course, this approach will not allow us to study changes of behaviour in these processes following the changes in the public policy scheme. However, we use this approach for processes that depend less on the current public policy. The two most important processes governed by nature are fertility and health shocks. For fertility we use data from the *Mexican Family Life Survey* to estimate the probability of having a child in a given year conditional on the education and the age of the mother (see details in section A.3.3.5.2). For the calibration of the health shock we estimated the probability of any health expenditure by age using the *Encuesta Nacional de Ingresos y Gastos de los Hogares* and use an indirect calibration for the size of the shock in order to reproduce the age structure observed in Mexico (see details in section A.3.3.5.1).

Chapter 4

Results

We present the results in two steps, first we discuss the baseline model in section 4.1 which aims at mimicking key statistics of the Mexican economy. The discussion will focus on the appropriateness of the model in capturing the main characteristics of the current situation in Mexico.

In section 4.2 we then use the model to simulate a policy change and discuss the results by comparing them to the baseline outcome.

4.1 Baseline model

The idea is to generate an artificial world that resembles the actual situation in Mexico. Of course, the mere complexity of the model will not allow us to reproduce all statistics, but we aim at generating a world that resembles sufficiently well the actual situation in order to run some policy analyses.

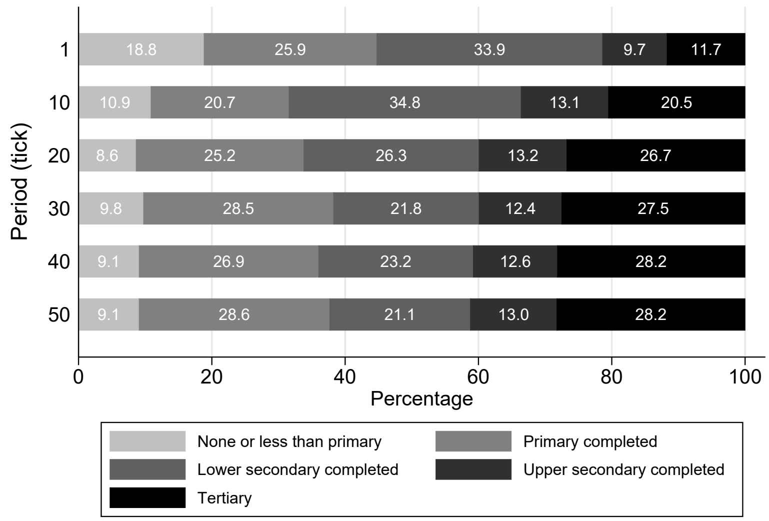
We mainly focus on statistics that are directly related to the studied phenomena and put somewhat less weight on other stylised facts. We simulated the baseline model for 100 different random seeds and ran it for 50 periods. We generally focus here on the later periods of each run, because the first periods are strongly influenced by the initial population. For instance, the education distribution of the initial period is simply the education distribution we found in the data. In contrast, the distribution after 50 periods of the simulation is only the result of the model. Hence, we can directly use the first periods as stylised facts and compare them to the outcome towards the end of each simulation run.

4.1.1 Education distribution

Education is a key element in our model, because it directly links to intergenerational mobility and to the labour market and eventually to the income distribution. Figure 4.1 shows the education distribution for individuals aged 25 to 40. We focus on this age range to make sure they are no longer enrolled and at the same time sufficiently young in order to see changes over time in the model.

In general, the years that people go to school increased with time, thus the model produces slightly more education than what we observe in reality. These changes take essentially place at the extremes of the distribution, where the share of people without education drops (from 18.8% to 9.1%) and the share of individuals with tertiary education increases (from 11.7% to 28.2%). Overall, we believe that these changes over time are not necessarily problematic, because the average education in Mexico is indeed increasing. This applies particularly to the very low level of education due to the fact that the number mandatory school years has been increased over the last decades. Hence, we might also expect the actual distribution to shift towards higher levels of education.

Figure 4.1: Distribution of education over time



Considering only individuals aged 25 to 40 years

A very important result we would like to highlight is the stability of the distribution after period 20. This will be very important for the policy analysis as we always introduce the policy in period 25.

4.1.2 Structure of the economy and formality

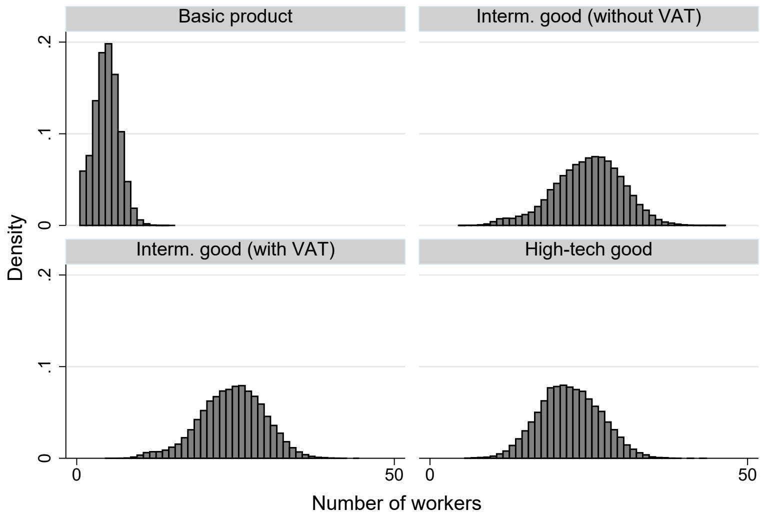
Let us now turn our attention to the firms and the structure of the economy. We initiate the different firms with different sizes but then let the model endogenously determine the best firm size for each type of firm. This decision is taken at the firm level through hiring and firing workers.

Figure 4.2 displays a histogram of the size of the firms by type. The size of the firms is measured by the number of workers they employ. All the results displayed in Figure 4.2 are based on period 25 to 50, thus no longer depending on the initial firm size we impose.

We can observe a dual economy with small firms producing the basic good and relatively bigger firms producing the intermediate and the high-tech good. The differences across the later three product types are almost indistinguishable. Interestingly the size of the firms within each type has a relatively large heterogeneity. For instance, the high-tech product is produced by firms with 12 up to almost 40 workers.

The density estimates in the histogram hide one important result with regard to the distribution of firms: the number of firms in each category. This information is displayed in Figure 4.3, where we show the distribution of types of firms by the number of firms (left) and the number of workers (right). We can see that there are many small firms producing the basic good. However, when we look at how many individuals work for these different types of firms, we see that the importance of the producers of basic products is much smaller. These differences are also observed in the data. According to the 2009 economic census from Mexico, around 95% of all firms had less than 10 workers, but they employ only about 45% of the labour force (INEGI, 2009). Thus, the proportion of small firms in our model is still somewhat too low, despite the impressive proportion of above 75%. In contrast, the number of workers employed by these small firms is reasonably close to the official figures.

Figure 4.2: Distribution of firm sizes by type of product



Besides the size and the distribution of firms, it is of particular interest to look at the formality status of these firms. The formality status of firms emerges from the model through the optimisation of firms. Figure 4.4 depicts the proportion of formal firms by type of firm on the left graph.

Basically all firms of intermediate goods without VAT and high-tech are formal or become formal after a few periods. In contrast, producers of the intermediate good that is subject to VAT are much more likely to be informal. At this stage it is interesting to notice that the only difference between the two intermediate goods is the VAT. Hence, the difference in the formality status is due to the larger disadvantage of being formal due to the payment of the value added tax. Informal firm can sell at the same price on the market, but keep the 16% of VAT as profit. Finally, the producer of the basic good are mostly informal and the share of formal firms only slowly increases over time.

The graph of the right side in Figure 4.4 shows an estimate of formality as a function of the firm size. This figure clearly points to a threshold (around 12-13 workers) after which it is better to be formal than informal.

To summarise the structure of the economy that emerges: the model produces a dual economy with larger, mainly formal firms producing more complex products and many small and mostly informal firms producing basic goods and services.

4.1.3 Economic growth

Let us now look at economic growth in our economy. The small open economy assumptions we use in this model results in a potential mismatch between consumption and production. In this section we therefore look at GDP only from the production side by computing the value of produced goods. In order not to confound changes in the domestic production with changes in the international prices[1], we always use the production at constant prices of period 25. Figure 4.5 shows the average growth rate per period in the model. Remember that all results shown in this section are based on 100 individual runs.

[1]These changes according to our price changing mechanism explained in section A.3.3.5.3.

Figure 4.3: Relative importance of firm types by number and number of workers

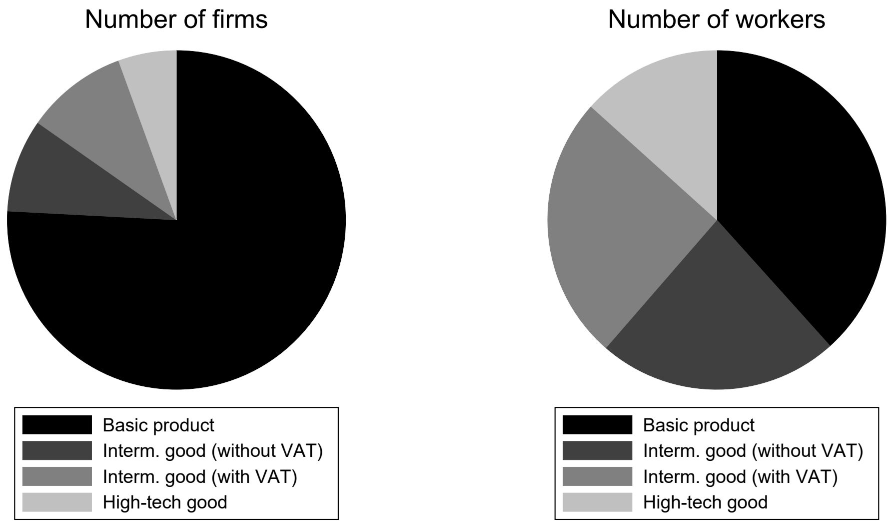


Figure 4.4: Proportion of formal firms by product type and size of the firm

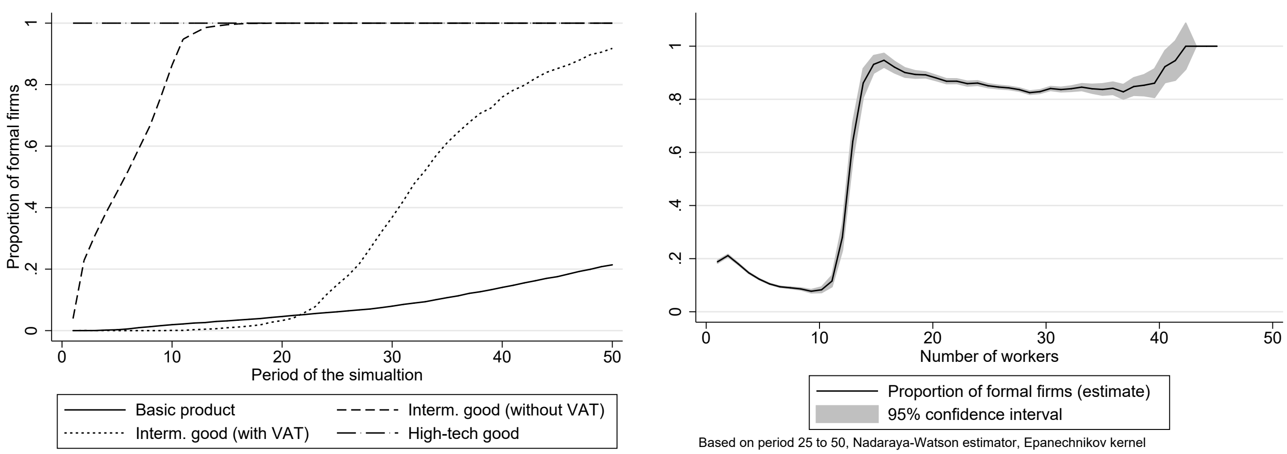
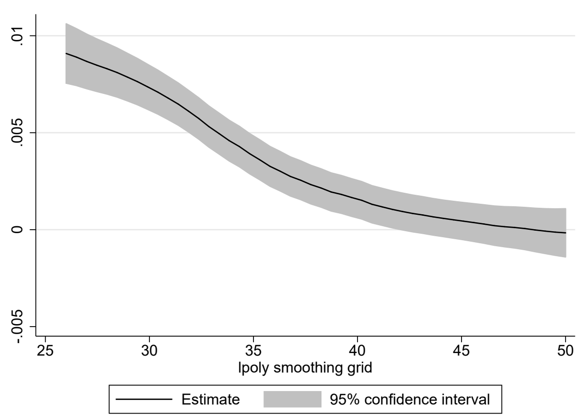


Figure 4.5: Average GDP growth rates at constant prices (period 25) over time

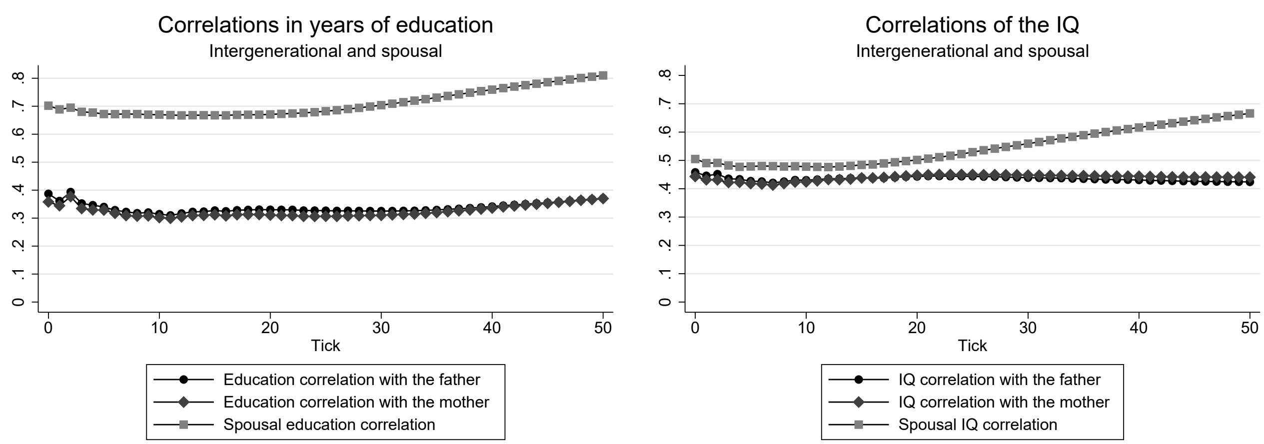


Several results can be derived from this figure. First, overall the growth level is very small, attaining a maximum value of around 1% at period 25. This low growth makes sense because we do not include any technological change in our model. Second, the growth rates go steadily towards zero and shortly after period 40 the average growth rate is no longer significantly different from zero.

4.1.4 Intergenerational correlations

After the production side of our model, we now focus on the family. First, we look at social mobility, which we measure with intergenerational correlations, mainly in education but also in IQ. Figure 4.6 displays the correlations in years of education (left) and the IQ (right) for both the intergenerational and the spousal relationship. We display the results for the whole 50-year period we simulated, because we can take the values at the beginning as stylised facts.

Figure 4.6: Intergenerational correlations



Overall we can observe a slight upward trend in the spousal correlations, both in terms of education and IQ. This is a direct effect of the mating process, where the model is probably slightly too deterministic, by excluding partnerships of very heterogeneous agents. In contrast, the intergenerational correlations are fairly well reproduced, even though it is important to mention that the values we observe in our initial population are lower than what other authors have found. For instance, Hertz et al. (2007) find an intergenerational education correlation of slightly above 0.5 for Mexico. These difference might be due to the fact that our initial population is based on families where children are still living in the household and therefore on average younger.

Nevertheless, it is important to highlight that the correlations are stable over time and within close range of the initial values. In our policy analysis we will always compare the values to the baseline, thus it is important that these baseline values are stable.

4.1.5 Inequality

Finally, let us have a look at the inequality measures produced by our model. Again, we focus on the period after tick 25 to avoid a strong influence of the initial population. Table 4.1 displays a series of inequality measures for different periods (ticks) of the model and compares them to the values found in Mexican data. We use the *Encuesta Nacional de Ingresos y Gastos de los Hogares* (ENIGH) 2014 and use the sampling weights to compute the true inequality measures. We opt for a comparison with the ENIGH rather than with the initial population of the MxFLS (input data) due to the lower quality of the income data in the latter.

Table 4.1: InequalityMeaures

Measure	Tick 30	Tick 40	Tick 50	ENIGH 2014
Labour income				
Gini coefficient	0.264	0.272	0.278	0.559
Mean log deviation	0.117	0.125	0.131	0.639
80-20 ratio	2.076	2.271	2.325	7.893
Total income				
Gini coefficient	0.545	0.546	0.539	0.518
Mean log deviation	0.525	0.530	0.516	0.470
80-20 ratio	2.357	2.611	2.701	4.127
Expenditures				
Gini coefficient	0.666	0.670	0.668	0.499
Mean log deviation	0.819	0.834	0.824	0.433
80-20 ratio	2.939	3.041	3.145	3.720

Notes: All inequality measures were computed on per capita values at the family level, both from the model and from ENIGH 2014. The estimates using the data from ENIGH 2014 we obtained using the expansion factors.

In addition to the traditionally used Gini index, we also use the Mean log deviation (MLD) and the 80-20 ratios. We include these additional measures for two reasons. First, as we will see, the comparison with the real data depends very much on the indicator we look at and second, the computation of the Gini Index is computationally intensive.

Independently of the inequality measure we use, the level of inequality in the labour income is substantially lower in the model as compared to the data. There are several reasons for this discrepancy. First, in our model we do not have extremely high salaries, thus the top of the distribution is much less skewed than in reality. On the other hand, focusing only on labour income is not straightforward in the ENIGH data and we might overestimate the inequality level there.

When we look at inequality of total family income per capita, the values produced by the model are extremely close to what we observe in reality. The Gini index is within 2 to 3 points and only the 80-20 ratio is somewhat different from what we see in the data.

Finally, when we look at family expenditures per capita, the model produces slightly more inequality that what we observe in the data. This holds true when we look at the Gini and the Mean log deviation. In terms of 80-20 ratio we are slightly below the reference values.

Overall, the model seems to produce a little bit less inequality that what we observe in reality.

4.2 Changes in the social security system

The main goal of this study is to analyse the effects of a change in the social security system on inequality, social mobility and growth. For this purpose, we now present the results of a series of simulations where we completely change the social security system by introducing the access to the full featured health care system to all individuals, independently of their formal labour market status. At the same time, we drop all social security contributions and finance the new universal system through the ordinary budget of the government.

As this reform is likely to increase the cost for the government, we simultaneously simulate changes in the tax structure of the country as discussed in the literature review. We change essentially there parameters of the tax system:

1. The general value added tax rate (π_{VATg}, currently 16%)
2. The reduced value added tax rate (π_{VATr}, currently 0%)
3. The corporate income tax (π_{CIT}, currently 30%)

The argument to modify the CIT is that formal firms have no longer to pay the social security contributions and therefore a slight increase in the CIT might be cost neutral for them. On the other hand, increasing the VAT is likely to be the most effective and generalised way to increase tax revenue. We particularly focus on the currently exempted products with a tax rate of 0%.

In a preliminary analysis we simulated a large number of combinations of the three tax rates. Most of the analyses schemes reduced the income of the government dramatically. We then limited the number of tax schemes to the most interesting schemes and increased the number of simulations. The following Table provides a summary of the interventions.

Table 4.2: Overview of policy interventions

	Baseline	No tax reform	Generalise VAT	Increase VAT	Gen. VAT + increase CIT	All increased
Setting number	0	1	2	3	4	5
Social security reform	no	yes	yes	yes	yes	yes
Tax reform	no	no	yes	yes	yes	yes
General VAT rate	16%	16%	16%	20%	16%	20%
Reduced VAT rate	0%	0%	16%	16%	16%	20%
Corporate income tax	30%	30%	35%	30%	40%	40%

The baseline model does not include any policy change. We then have five schemes under which the dual system is changed to a universal system in period 25. This policy measure is identical in all settings and the only differences is the tax reform to finance this change. In the first setting we do not change the current tax system. This will allows us to isolate the pure effect of the social security reform. The remaining four settings include increases in the tax rates. Setting 2 introduced the VAT to products that were previously exempted and slightly increase the corporate income tax. We call this setting *Generalise VAT* because we increase the reduced VAT rate from 0% to the general VAT rate of 16%.

In setting 3 we do not modify the corporate income tax but increase the VAT rate of the products that were already taxed. Setting 4 includes the generalisation of the VAT rate (similar to setting 2), and a stronger increase of the corporate income tax. Finally, setting 5 increases all taxes quite strongly.

4.2.1 Simulation approach

In order to evaluate the effect of these different reforms, we simulated each policy reform for 25 different random seeds. Together with the baseline model in which no policy change takes place, this sums up to a total of 150 runs.

For each random seed we first simulated 25 periods before the policy change and another 25 periods under the new policy scheme. Of course, in the baseline setting - to which we compare the results to - no changes were introduced. The reasoning behind this approach is that we want to introduce the policy change once the model is stable and no longer depends on the initial conditions. Simulating 25 period under the new policy allows us to analyse not only the short run effects, but also some medium- and long-run consequence.

4.2.1.1 Expected results

Despite the complexity of the model, we can imagine a series of possible consequences of this dramatic policy change. First, the income and expenditure structure of the government mechanically changes. Income from social security contributions immediately go to zero. The same happens to the non-contributory health care services. For the remaining elements of government income, the consequences are not so clear. We might expect total government income to fall, but there is also the possibility that dropping the social security contributions makes formality more interesting, which could then lead to an increase of tax collection through income taxes. On the family side, we could expect a decrease of inequality and an increase of social mobility because the poorest now suddenly have access to better health care, which should help them both at school and in the labour market.

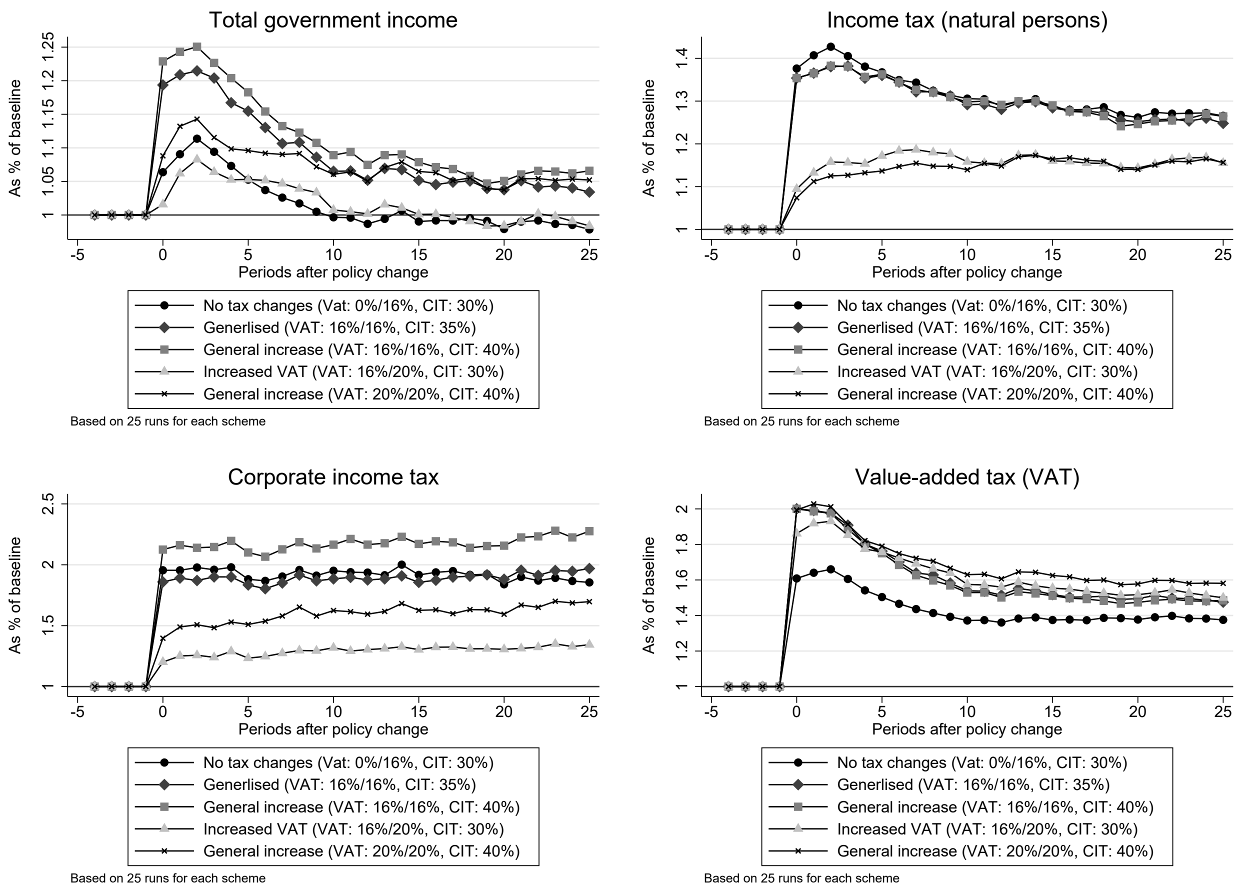
4.2.2 Effects on the government income

Before analysing the effects on growth, inequality and social mobility, we have to focus on the budget neutrality of the reform. Given that such a substantial change in the social security system and in particular in the funding structure can have important consequences for the overall government budget, we aim at simulating close-to budget neutral situations. For this, we focus on the combined total income of the social security system and the government before the change and compare it to the overall income after the change. Figure 4.7 displays total government income and its components as percentage of the baseline outcome and in function of the time since the policy change. A value of 1.1 for instance would suggest that under the policy change government income is 10% higher as compared to the baseline model. Each point in the graph is the average change when considering all 25 random seeds.

The results are quite striking in several aspects. First, total government income increases under this policy change, even though the social security contributions were dropped. This even holds true when we do not change the tax system at all (black line). The reason for this surprising increase is that more firms become formal, which increases all types of tax revenues. In the next subsection we will discuss this change in more detail. For instance, income tax of firms almost doubles, while the income from the value added tax and the income tax of natural persons also substantially increase.

A second very interesting result is the heterogeneity and the lack thereof across the different tax schemes. In terms of total increase of government income, the most two extreme cases yield the worst results. When not changing at all the tax rates, the loss of social security contribution can just be compensated through the increased number of formal firms. On the other hand, when the policy change is paid through a massive increase of all taxes, the change to formality is reduced. For the remaining three tax schemes the results are remarkably similar. The total income of the government increase by about 20 percent in the short run and then converges to about 5% above the baseline model. This reduction in the long run as compared to the short run is due to the evolution in terms of value added tax and income tax of natural persons. In contrast, the corporate income tax revenue of the government remains stable after the policy change.

Figure 4.7: Government revenue

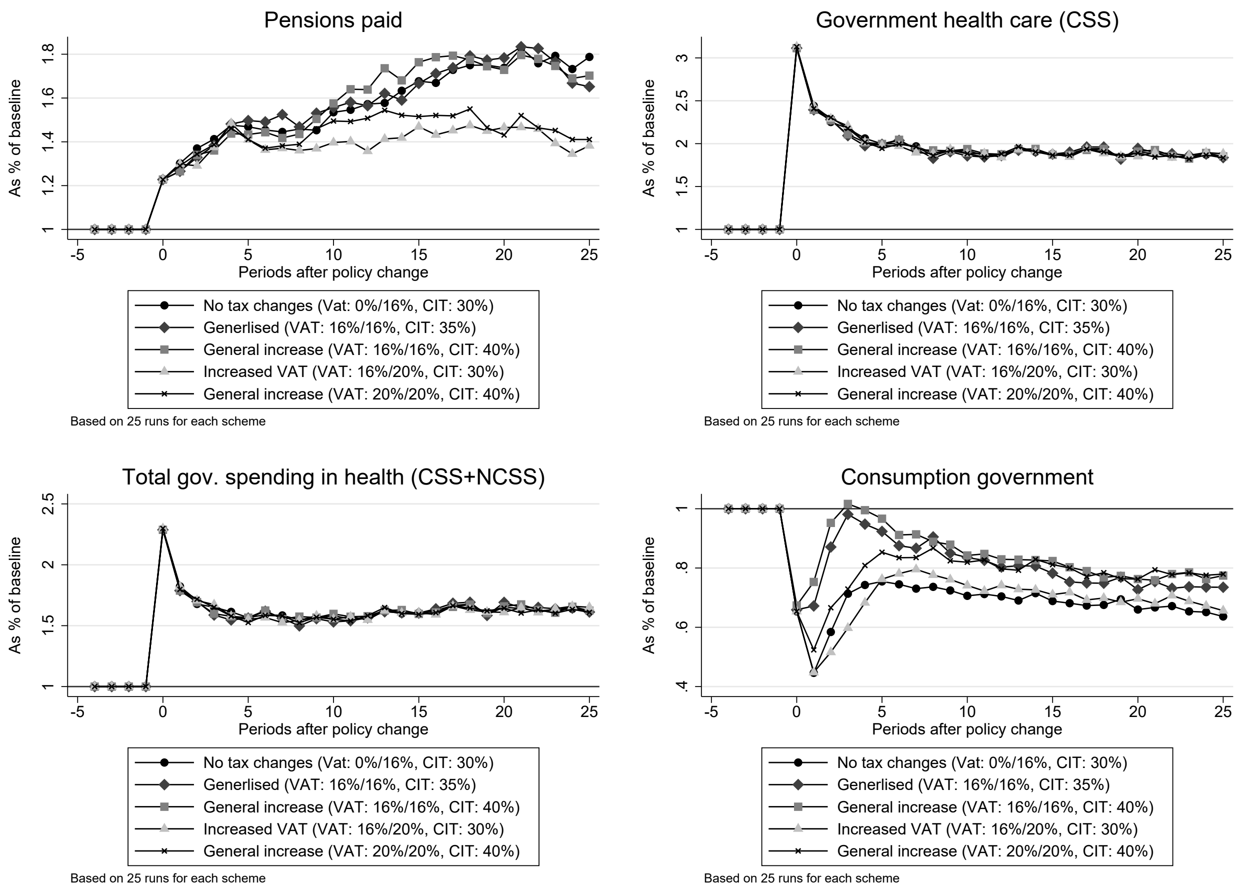


Of course, it is not sufficient to look at the income alone, because we expect the expenditure level to increase dramatically as well. Figure 4.8 displays similar graphs than Figure 4.7, but focuses on the expenditure side.

The amount of pensions paid and the government health care expenditures increase once the policy change takes place. In the case of health care, we observe a peek at the very beginning followed by a stabilisation at a slightly lower level. Looking at total health care expenditures, the government spends roughly 50% more under the new scheme. The pensions to not seem to stabilise very quickly. This steady increase is due to the fact that eligibility of pensions is linked to a minimum years of labour experience in the formal sector. Hence, many individuals do not qualify at the beginning, but given the increased formality in the economy, more and more people become eligible over the time.

Finally, by looking at the government consumption we have an idea of the overall result on the government side. Remember that government consumption is basically defined by the difference of income and the mandatory expenditures such as health care and pensions. Hence the values below unity we observe on the last graph of figure 4.8 suggest that the government budget is tighter under the reform. The smallest reduction is observed for the tax scheme 16-16-40, where we generalise the VAT and substantially increase corporate income tax. In contrast, the most extreme tax reform (20-20-40) provides rather poor results in terms of government consumption.

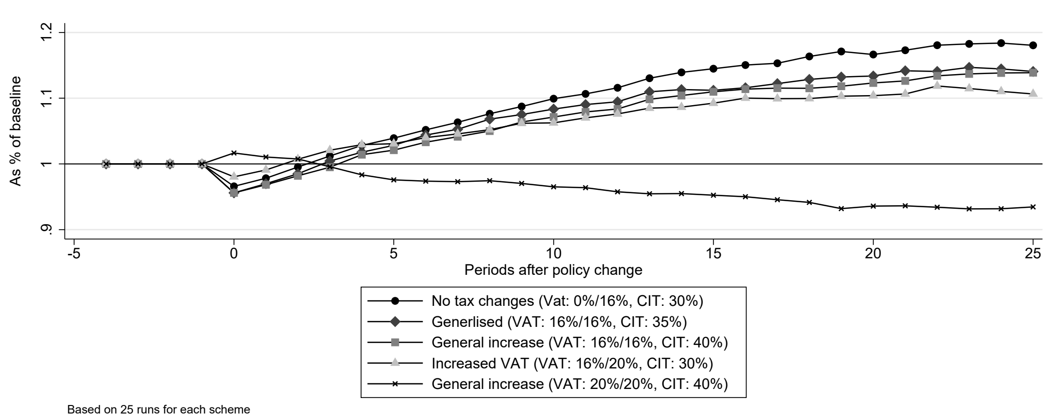
Figure 4.8: Government expenditure



4.2.3 Effects on growth and formality

We are now turning our attention to the main objectives of the study: growth, inequality and social mobility. Starting with the effects on GDP, we use the same type of graphs as before. Figure 4.9 displays the relative evolution of the GDP (not GDP growth).

Figure 4.9: Evolution of GDP as compared to the baseline model



Again, despite the large differences in the tax reforms we simulate, we find surprisingly little differences in the effects on the GDP. In all settings we have an initial loss of GDP of around 5%. Already after 3-4 years, the GDP level under the policy reform reaches the baseline values and becomes larger thereafter. In the medium and long run the GDP appears to be around 15% higher under the new policy scheme. In terms of GDP growth, the setting with no tax reforms seems to perform best, while the last setting with the massive increase in all types of taxes performs worst. The remaining settings all provide very similar results.

Figure 4.10: Evolution of the proportion of formal firms

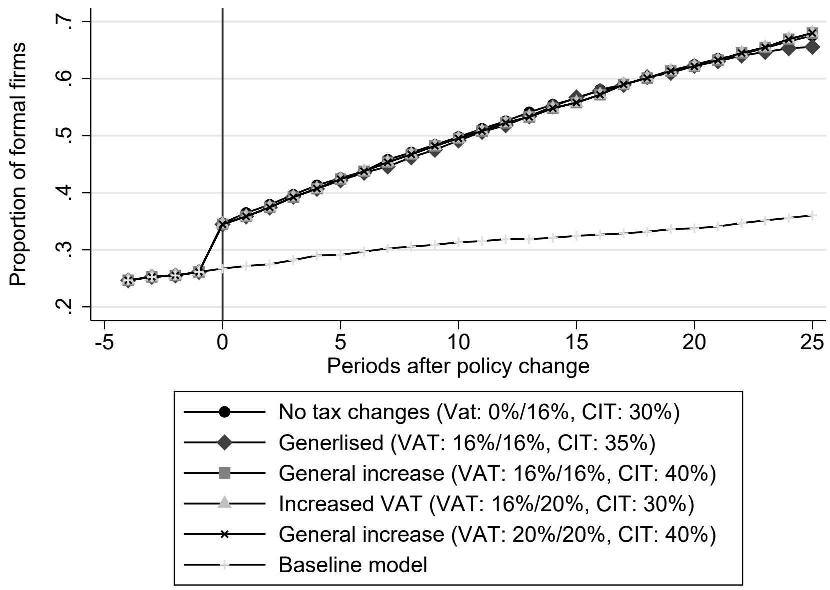


Figure 4.10 displays the average proportion of formal firms in levels. We observe a steady but slow increase in the baseline model. In all other settings we have a discontinuous increase once the new social security policy is implemented. This result must be due to the elimination of the social security contributions, which reduces the cost of being formal dramatically. In addition to the discontinuous jump in period zero, the steady increase of formal firms takes place at a substantially higher pace under the new policy scheme. This result is very similar for all but the most extreme tax scheme.

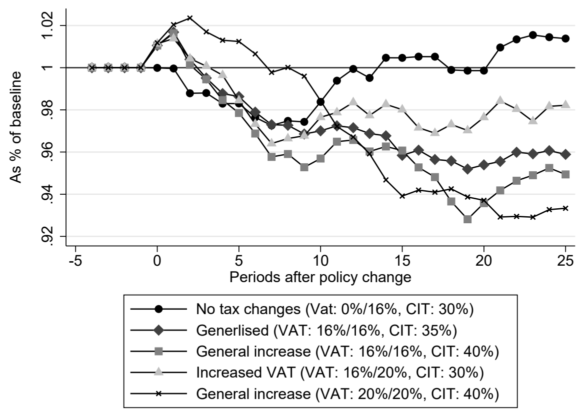
Looking at these results we might conclude that the beneficial effect we found up to this point are mostly driven by a substantial move to formality.

4.2.4 Effects on inequality

The important question now is whether these changes also have beneficial effects in terms of inequality and social mobility. Let us first look at income inequality. Figure 4.11 displays the ratio between the mean log deviation of income under the policy scheme and the baseline model. In this case, we find some more heterogeneous effects.

Under all schemes that involve a change in the tax structure, we observe an increase in income inequality during the first periods. Afterwards, the inequality level decreases in most cases. For the most extreme setting, this process of falling inequality takes more time, but once it falls, the levels attained are lower compared to the other settings. The setting without a tax reform more of less remains at the same values as the baseline model. The

Figure 4.11: Effects on income inequality



intermediate settings all reduce the inequality measure by some modest 4% to 5%. The comparison of setting 1 with the remaining settings suggest that the reduction in inequality is due to the tax reform, rather than to the social security reform.

Table 4.3 provides a more quantitative way to look at the same results. We simply regressed the inequality measure on a set of binary indicators identifying the policy setting. We ran this analysis for the short-, medium- and long-run.

Table 4.3: Effects on income inequality

	Income inequality (MLD)		
	Short run	Medium run	Long run
Baseline	0.371***	0.386***	0.387***
	(0.001)	(0.002)	(0.001)
Policy change, no fiscal change	-0.004**	-0.009***	0.002
	(0.002)	(0.002)	(0.002)
Policy change, 16 16 35	-0.001	-0.010***	-0.015***
	(0.002)	(0.002)	(0.002)
Policy change, 16 16 40	-0.002	-0.015***	-0.019***
	(0.002)	(0.002)	(0.002)
Policy change, 20 16 30	-0.000	-0.011***	-0.009***
	(0.002)	(0.002)	(0.002)
Policy change, 20 20 40	0.002	-0.009***	-0.020***
	(0.002)	(0.002)	(0.002)
N	750	900	2250
Adj. R^2	0.008	0.047	0.094

Notes: OLS regression using data from 25 simulations of each setting and several periods. *Short run* refers to 1 to 5 years after the policy change, *Medium run* to 5 to 10 years and *Long run* to 10 to 25 years. The number in the settings refer to the tax rates in percentage for the regular VAT, the reduced VAT and the corporate income tax respectively

The effects in the short run (1 to 5 years) are mostly not significant. In the long run the reductions are significant and range somewhere between 0.01 and 0.02 on the scale of the mean log deviation.

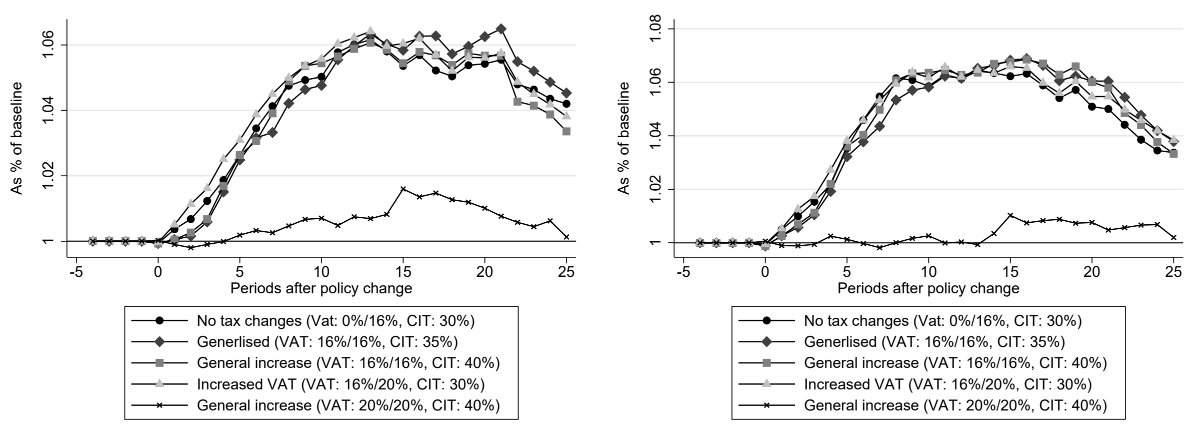
Overall, these effects do have the expected sign, but their magnitude is very small, especially given the radical policy change we simulate.

4.2.5 Effects on social mobility

We now turn to social mobility, where we focus on intergenerational education mobility. A first and very simple measure is the correlation between the years of education of the parents and the children. Due to the strong linearity assumption of this metric, we also include other measures such as an estimate of inequality of educational opportunities using the methodology proposed by Ferreira and Gignoux (2014) and the transition matrices.

Figure 4.12 depicts the evolution of the intergenerational correlations in education. In both graphs we show the ratio of the correlation under the policy intervention and the correlation in the baseline model.

Figure 4.12: Effects on intergenerational education mobilty



In general, we can observe four interesting facts: 1) both correlations increase after the policy change; 2) the correlations do not present big differences among the five types of fiscal structures, except for the most extreme tax reform 3) the increase is steady for a few years and then starts to stabilise first before slightly decreasing 4) both correlations are very similar.

As for inequality, we also present a regression in Table 4.4, allowing us to see whether the changes are significant or not. We estimate a simple linear regression model where we explain the correlation by policy setting. We do this for the short (1-5 years), medium (5 to 10 years) and the long (11-25 years) run. As we can see in the graphs, the increases are generally significant but do not exceed two points in terms of correlation.

Hence, the results in terms of social mobility are different from what we expected, because increased intergenerational correlations suggest a lower level of social mobility. However, there are a few things to consider. The correlation measure is very crude and the linearity assumption might be problematic, especially when considering the changes in the education structure of the population. Second, although we observe an increase in the correlations, these are very small and do not represent a dramatic decrease of social mobility.

Given that the linear correlation in education is a very crude measure, we now explore two alternative measures of social mobility in education. First we look at a measure of inequality of educational opportunities introduced by Ferreira and Gignoux (2014). The idea of this measure is to explain the years of education of the child by the circumstances of the child. In this case we limit the set of circumstances to the education of the father and the mother and include these variables by a series of dummies in order to achieve the highest possible flexibility and not relying on a linearity assumption. The measure of inequality of opportunity is then the R-squared of a linear regression. This is the proportion of total variation in the education of the children that is explained by the education of the parents. Figure 4.13 displays these estimates for all policy settings.

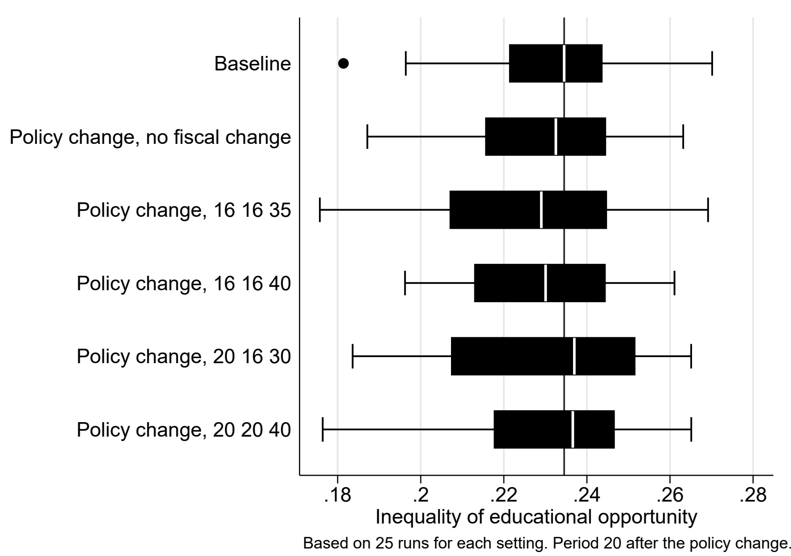
Table 4.4: Effects on social mobility

	Correlation with the father			Correlation with the mother		
	Short run	Medium run	Long run	Short run	Medium run	Long run
Baseline	0.332***	0.333***	0.355***	0.317***	0.322***	0.352***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)
Policy change, no fiscal change	0.004	0.014***	0.019***	0.006*	0.017***	0.019***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)
Policy change, 16 16 35	0.003	0.013***	0.020***	0.004	0.015***	0.021***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)
Policy change, 16 16 40	0.004	0.014***	0.018***	0.005	0.017***	0.020***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)
Policy change, 20 16 30	0.006**	0.015***	0.019***	0.006**	0.017***	0.020***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)
Policy change, 20 20 40	0.004	0.015***	0.022***	0.006*	0.017***	0.021***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)
N	750	900	2250	750	900	2250
Adj. R^2	-0.001	0.051	0.101	0.000	0.057	0.090

Notes: OLS regression using data from 25 simulations of each setting and several periods. *Short run* refers to 1 to 5 years after the policy change, *Medium run* to 5 to 10 years and *Long run* to 10 to 25 years. The number in the settings refer to the tax rates in percentage for the regular VAT, the reduced VAT and the corporate income tax respectively

Contrary to the simple correlation, we now find a slight increase in social mobility, because the explanatory power of parental education is somewhat smaller under the policy change. This holds true for all but the last two settings, where both the average and the median are above the reference values of the baseline model. However, the gain under the first three policy settings are also modest and the variation in the estimation depending on the random seed is substantial. In setting 2 (16-16-35) we find the most promising results, but also a strong variability of the measure. The median of the inequality of opportunity measure is decreased by slightly less than one point, which is quite modest.

Figure 4.13: Inequality of educational opportunities by policy setting



Finally, we look at educational mobility form a yet another perspective by analysing the transition probabilities. Table 4.5 displays the transition matrix for the father-child relationship[2]. The probabilities indicate the conditional

[2]We limit the analysis to the relationship with the father, given that the results with the mother are virtually the same.

probability of achieving a certain level of education given the level of education of the father. The transition matrix shows two interesting facts: 1) the probability of having more education is higher when the father has more education, 2) with the implementation of the new policy, the probability of having less education than the father is reduced and the probability of having more education is increased.

These results are relatively difficult to interpret in terms of relative social mobility, but are quite clear in terms of absolute social mobility. It seems that the social security reform induces more education for all levels of parental education. This effect seems to be due more to the social security reform than to the tax reform, because the results between setting 1 (no tax reform) and the other settings are very similar.

We find particularly strong effects for children with parents having lower or higher secondary schooling. For instance, the likelihood of a university degree increases from around 28% to 32.5% for children whose father has lower secondary education.

Table 4.5: Transition matrix by policy scheme

		Child's education				
Father's education	**Policy setting**	**Less than primary**	**Primary**	**Lower secondary**	**Higher secondary**	**University**
None or less than primary	Baseline	18.6%	38.8%	24.9%	8.7%	9.0%
	Only policy change	17.6%	38.9%	24.2%	9.5%	9.9%
	Policy change, 16 16 35	16.9%	39.6%	24.3%	9.0%	10.2%
	Policy change, 16 16 40	17.0%	39.9%	24.4%	8.4%	10.3%
	Policy change, 20 16 30	17.4%	39.3%	24.0%	9.2%	10.1%
	Policy change, 20 20 40	17.0%	39.1%	24.2%	9.2%	10.5%
Primary completed	Baseline	10.8%	41.0%	23.9%	9.9%	14.4%
	Only policy change	9.6%	39.9%	22.6%	11.2%	16.8%
	Policy change, 16 16 35	9.6%	40.4%	21.7%	11.3%	17.0%
	Policy change, 16 16 40	9.5%	40.5%	21.8%	11.2%	17.0%
	Policy change, 20 16 30	9.5%	40.2%	21.9%	11.1%	17.2%
	Policy change, 20 20 40	9.4%	40.4%	22.1%	10.3%	17.8%
Lower secondary completed	Baseline	7.5%	24.9%	24.7%	14.9%	28.1%
	Only policy change	6.6%	23.3%	24.0%	13.7%	32.4%
	Policy change, 16 16 35	6.8%	22.9%	24.2%	13.7%	32.4%
	Policy change, 16 16 40	6.8%	23.0%	24.0%	13.7%	32.5%
	Policy change, 20 16 30	6.8%	22.9%	23.9%	13.5%	33.0%
	Policy change, 20 20 40	6.6%	22.7%	24.0%	14.1%	32.5%
Higher secondary completed	Baseline	5.4%	16.6%	20.9%	16.5%	40.7%
	Only policy change	4.3%	14.5%	20.3%	15.4%	45.5%
	Policy change, 16 16 35	4.3%	14.7%	19.4%	14.7%	47.0%
	Policy change, 16 16 40	4.6%	14.7%	19.5%	14.7%	46.6%
	Policy change, 20 16 30	3.9%	14.4%	19.6%	15.2%	46.8%
	Policy change, 20 20 40	4.1%	14.1%	19.6%	14.9%	47.2%
University	Baseline	2.9%	7.6%	13.5%	15.7%	60.3%
	Only policy change	2.5%	6.3%	12.8%	15.4%	63.0%
	Policy change, 16 16 35	2.6%	6.8%	12.4%	14.7%	63.6%
	Policy change, 16 16 40	2.6%	6.6%	12.8%	14.4%	63.7%
	Policy change, 20 16 30	2.6%	6.4%	12.2%	15.1%	63.7%
	Policy change, 20 20 40	2.6%	6.7%	12.2%	15.3%	63.2%

Notes: Based on period 20 after the policy change (long term effect) and focusing only on individuals having finished their education and aged between 25 and 40 years. For each policy setting we ran 25 simulations and computed the transition probabilities on the pooled sample of all 25 simulations. These pooled samples include roughly 27'000 individuals each.

To sum up the effect of the reforms on social mobility, it seems that in terms of relative social mobility the effects are at most modest. In terms of absolute social mobility, we find some more beneficial effects, but they are still rather small compared to the massive policy intervention.

Chapter 5

Conclusion

In this study we developed a rather complex model of the Mexican economy in order to analyse the effects of changes in the social security system on inequality, social mobility and economic growth. The model uses agent-base modelling techniques and includes a variety of processes and mechanisms known to matter for at least one of the aforementioned phenomena. In this regard, we consider for instance assortative mating, education dependent fertility and matching frictions in the labour market.

The baseline model reproduced the actual statistics for Mexico within a reasonable range. Some values such as income inequality almost perfectly fit the data, while other statistics such as the intergenerational correlations in education are somewhat below the values observed in the data. Overall, the model seems to produce an economy that is reasonably close to the Mexican reality and that allows us to carry out simulations of public policy changes.

Our policy simulation is based on suggested reforms of the social security and the tax system. The major change in the social security system is to move from the currently implemented dual system to a universal system. In the current dual system formal workers and their family members have access to a full-fledged contributory social security system (IMSS or ISSSTE). In contrast, informal workers have only access to a non-contributory social security system (Seguro Popular) that includes substantially less services. The proposed reform eliminates this non-contributory social security system and removes all contributions to the contributory system. Moreover, the new system will be open to all individual independently of their formality status and it will be financed through the ordinary government budget. For this reason, the proposed reform of the social security system is accompanied by a tax reform. In this study we consider increases in both the value-added tax and the corporate income tax.

The results of our simulation study suggest that these changes might indeed increase GDP. However, this increase does not seem to be due to the suggested mechanism going through a reduction of inequality and an increase of social mobility. These two phenomena change only very little. For instance, income inequality is reduced by a modest 5% and relative intergenerational social mobility does not seem to change. In contrast, absolute intergenerational mobility in education is positively affected by the policy change, which is of course a beneficial result. According to our interpretation of the results, the GDP change is essentially due to increased formality. The proportion of formal firms discontinuously increases upon the policy change and then continues to increase faster than in the baseline model. This result is due to the elimination of social security contributions, which are especially for low wages quite high under the current system.

It is important to mention again the fact that the model presented in this study is a first attempt to answer the research question and to reproduce the Mexican economy appropriately. While we believe that the current version of this model largely succeeds, there is a number of limitations that must be mentioned. First, a number of processes have been implemented in a simplistic way. For instance, schools and the health sector are only implemented in a passive way. Future developments of the model might want to model these processes with more detail, allows us to look at more detailed effects of social policies. Second, the calibration and the sensitivity analyses of such a complex model are difficult and time intensive tasks. The main reason for this is that virtually any parameter can affect the model in various ways, thus when changing parameters, we must monitor both results that are closely related to the parameter and parts of the model that are seemingly unrelated.

As a consequence, the model presented in this study must be seen as a first attempt and input for future research. We see several tasks for future research. As suggested by Chávez-Juárez (2016), agent-based models mostly raise new questions that can be addressed by empirical analyses. These results can then be included in a revised version of the model. In our particular case we suggest looking closely at the family behaviour and compare it to the data. During the development of this model we considered different approaches to model the family behaviour. Eventually, we used the rather traditional utility maximisation approach. It would therefore be important to validate this choice through empirical analyses.

In terms of policy analysis, throughout the development of the model, we identified a number of quite complex processes on the government side. For instance, the contributory social insurance contributions are extremely complicated to compute, very high for low wages and seems to be highly regressive. It could be interesting to simulate changes to these mechanisms without the big change of moving to a universal social security.

Another interesting policy change would be the addition of elements to social security. For instance, the current system does not include unemployment insurance, which would be an important element for social mobility.

Bibliography

Albrecht, James, Lucas Navarro, and Susan Vroman, "The Effects of Labour Market Policies in an Economy with an Informal Sector*," *The Economic Journal*, 2009, *119* (539), 1105–1129.

Alfonso, Mariana, "Credit Constraints and the Demand for Higher Education in Latin America," Inter-American Development Bank - Education Division - SCL, Working Paper #3 2009.

Andrews, Dan and Andrew Leigh, "More inequality, less social mobility," *Applied Economics Letters*, 2009, *16* (15), 1489–1492.

Anger, Silke and Guido Heineck, "Do smart parents raise smart children? The intergenerational transmission of cognitive abilities," *Journal of Population Economics*, 2010, *23*, pp. 1255–1282.

Antón, Arturo, Fausto Hernández, and Santiago Levy Algazi, "The end of informality in México?: fiscal reform for universal social insurance," 2012.

Basu, Arnab K., Nancy H. Chau, and Ravi Kanbur, "Contractual Dualism, Market Power and Informality," *The Economic Journal*, 2015, *125* (589), 1534–1573.

Becker, Gary S, "A theory of marriage: Part I," *The Journal of Political Economy*, 1973, pp. 813–846.

Becker, Gary S., *Human Capital*, Columbia University Press, New York, 1975.

Becker, Gary S, *Human capital: A theoretical and empirical analysis, with special reference to education*, University of Chicago press, 2009.

Becker, Gary S. and Nigel Tomes, "Human Capital and the Rise and Fall of Families," *Journal of Labor Economics*, 1986, *4* (3, Part 2), S1–S39.

Björklund, Anders and Markus Jäntti, "Intergenerational income mobility in Sweden compared to the United States," *The American Economic Review*, 1997, *87* (5), 1009–1018.

Björklund, Anders, Karin Hederos Eriksson, and Markus Jäntti, "IQ and Family Background: Are Associations Strong or Weak?," *The B.E. Journal of Economic Analysis & Policy*, 2010, *10* (1).

Black, Sandra E., Paul J. Devereux, and Kjell G. Salvances, "Like Father, Like Son? A Note on the Intergenerational Transmission of IQ Scores," *Economic Letters*, 2009, *105* (1), pp. 138–140.

Bound, John and Sarah Turner, "Chapter 8 - Dropouts and Diplomas: The Divergence in Collegiate Outcomes," in Stephen Machin Eric A. Hanushek and Ludger Woessmann, eds., *Handbook of The Economics of Education*, Vol. 4, Elsevier, 2011, pp. 573 – 613.

Busso, Matías, María Victoria Fazio, and Santiago Levy, "(In)Formal and (Un)Productive: The Productivity Costs of Excessive Informality in Mexico," IDB Working Paper Series No. IDP-WP-341, August 2012, Inter-American Development Bank 2012.

Campos Vázquez, Raymundo Miguel, Emmanuel Salavador Chávez Jiménez, and Gerardo Esquivel Hernández, "Los Ingresos Altos, la Tributación Óptima y la Recaudación Posible," 2014.

Carneiro, Pedro and James J. Heckman, "The Evidence on Credit Constraints in Post-Secondary Schooling," *The Economic Journal*, 2002, *112* (482), 705–734.

CEPAL and OXFAM, "Tributación para un crecimiento inclusivo," Technical report published by Comisión Económica para América Latina y el Caribe (CEPAL) and Oxfam. Available at http://www.cepal.org/es/publicaciones/39949-tributacion-un-crecimiento-inclusivo (November 2016) 2016.

Checchi, Daniele, Andrea Ichino, and Aldo Rustichini, "More Equal but Less Mobile? Education Financing and Intergenerational Mobility in Italy and in the United States," CEPR Discussion Papers 1496, C.E.P.R. Discussion Papers October 1996.

Chávez-Juárez, Florian, "The Effect of Cash Transfer Programs on Educational Mobility-An Agent Based Approach," Working Paper, CIDE, mimeo. 2015.

_ , "On the Role of Agent-based Modeling in the Theory of Development Economics," *Review of Development Economics*, 2016, *Online First*, Available at http://dx.doi.org/10.1111/rode.12264.

Corak, Miles, "Income inequality, equality of opportunity, and intergenerational mobility," *The Journal of Economic Perspectives*, 2013, *27* (3), 79–102.

Diamond, Peter A., "Wage Determination and Efficiency in Search Equilibrium," *The Review of Economic Studies*, 1982, *49* (2), 217–227.

Djankov, Simeon, Rafael La Porta, Florencio Lopez de Silanes, and Andrei Shleifer, "The Regulation of Entry," *The Quarterly Journal of Economics*, 2002, *117* (1), 1–37.

Duryea, Suzanne, David Lam, and Deborah Levison, "Effects of economic shocks on children's employment and schooling in Brazil," *Journal of development economics*, 2007, *84* (1), 188–214.

Erikson, Robert and John H Goldthorpe, *The constant flux: A study of class mobility in industrial societies*, Oxford University Press, USA, 1991.

Ermisch, John, Marco Francesconi, and Thomas Siedler, "Intergenerational Mobility and Marital Sorting," *The Economic Journal*, 2006, *116* (513), pp. 659–679.

Ferreira, Francisco H.G. and Jérémie Gignoux, "The Measurement of Educational Inequality: Achievement and Opportunity," *The World Bank Economics Review*, 2014, *28* (2), 210–246.

Galor, Oded and Joseph Zeira, "Income Distribution and Macroeconomics," *The Review of Economic Studies*, 1993, *60* (1), 35–52.

Gilbert, Nigel, *Agent Based Models*, 1st ed., Series: Quantitative Applications in Social Sciences. SAGE Publications, 2008.

Grimm, Volker, Uta Berger, Donald L. DeAngelis, J. Gary Polhill, Jarl Giske, and Steven F. Railsback, "The ODD protocol: A review and first update," *Ecological Modelling*, 2010, *221* (23), pp.2760–2768.

_ , _ , Finn Bastiansen, Sigrunn Eliassen, Vincent Ginot, Jarl Giske, John Goss-Custard, Tamara Grand, Simone K. Heinz, Geir Huse, Andreas Huth, Jane U. Jepsen, Christian Jørgensen, Wolf M. Mooij, Birgit Müller, Guy Peer, Cyril Piou, Steven F. Railsback, Andrew M. Robbins, Martha M. Robbins, Eva Rossmanith, Nadja Rüger, Espen Strand, Sami Souissi, Richard A. Stillman, Rune Vabø, Ute Visser, and Donald L. DeAngelis, "A standard protocol for describing individual-based and agent-based models," *Ecological Modelling*, 2006, *198* (1), pp. 115–126.

Grossman, Michael, "On the Concept of Health Capital and the Demand for Health," *Journal of Political Economy*, 1972, *80* (2), pp. 223–255.

Hamill, Lynne and Nigel Gilbert, *Agent-Based Modelling in Economics*, John Wiley & Sons, 2015.

Harris, John R and Michael P Todaro, "Migration, unemployment and development: a two-sector analysis," *The American economic review*, 1970, pp. 126–142.

Hertz, Tom, Tamara Jayasundera, Patrizio Piraino, Sibel Selcuk, Nicole Smith, and Alina Verashchagina, "The Inheritance of Educational Inequality: International Comparisons and Fifty-Year Trends," *The B.E. Journal of Economic Analysis & Policy*, 2007, *7* (2), 1–46.

INEGI, "Micro, pequeña, mediana y gran empresa : estratificación de los establecimientos : Censos Económicos 2009," Instituto Nacional de Estadística y Geografía, México. Available at `http://www.inegi.org.mx/est/contenidos/espanol/proyectos/censos/ce2009/pdf/Mono_Micro_peque_mediana.pdf` 2009.

Lewis, W Arthur, "Economic development with unlimited supplies of labour," *The manchester school*, 1954, *22* (2), 139–191.

Loury, Glenn C., "Intergenerational transfers and the distritbution of earnings," *Econmetrica*, 1981, *49* (4), 843–867.

Maloney, William F, "Informality revisited," *World Development*, 2004, *32* (7), 1159–1178.

Maoz, Yishay D and Omer Moav, "Intergenerational mobility and the process of development," *The Economic Journal*, 1999, *109* (458), 677–697.

Miller, John H. and Scott E. Page, *Complex Adaptive Systems - An introduction to computational model of social life*, Princeton University Press, 2007.

OECD, "In It Together: Why Less Inequality Benefits All," OECD Publishing, Paris. Available at `http://dx.doi.org/10.1787/9789264235120-en` 2015.

Ozdural, Sanem, "Intergenerational mobility: A comparative study between Turkey and the United States," *Economics letters*, 1993, *43* (2), 221–230.

Petrongolo, Barbara and Christopher A Pissarides, "Looking into the black box: A survey of the matching function," *Journal of Economic literature*, 2001, *39* (2), 390–431.

Polhill, J. Gary, "ODD Updated," *Journal of Artificial Societies and Social Simulation*, 2013, *4* (9), Aritcle 9, http://jasss.soc.surrey.ac.uk/13/4/9.html.

Secretaría de Salud, "Aviso que establece los niveles de las Cuotas Familiares del Sistema de Protección Social en Salud para el Ejercicio Fiscal 2016," Diario Oficial de la Federación, 31 de marzo de 2016, México. Retrieved from: http://dof.gob.mx/nota_detalle.php?codigo=5431525&fecha=31/03/2016 2016.

Seguro Popular, "Website of the Seguro Popular," http://www.seguro-popular.gob.mx/ (Accessed in August 2016) 2016.

Straub, Stéphane, "Informal sector: the credit market channel," *Journal of Development Economics*, 2005, *78* (2), 299–321.

Thiessen, Del and Barbara Gregg, "Human Assortative Mating and Genetic Equilibrium: An Evolutionary Perspective," *Ethology and Sociobiology*, 1980, *1* (2), pp. 111–140.

Torche, Florencia, "Intergenerational Mobility and Inequality: The Latin American Case*," *Annual Review of Sociology*, 2014, *40*, 619–642.

van Leeuwen, Marieke, Stéphanie van den Berg, and Dorret Boomsma, "A twin-family study of general IQ," *Learning and Individual Differences*, 2008, *18*, pp. 76–88.

Wendelspiess Chávez Juárez, Florian, "Intergenerational Transmission of Education: The Relative Importance of Transmission Channels," *Latin American Economic Review*, 2015, *24* (1), pp. 1–44.

Woldehanna, Tassew and Adiam Hagos, "Economic shocks and children's dropout from primary school: implications for education policy in Ethiopia," *Africa Education Review*, 2015, *12* (1), 28–47.

Wolf, Pedro S.A. and Aurelio José Figueredo, "Fecundity, Offspring Longevity, and Assortative Mating: Parametric Tradeoffs in Sexual and Life History Strategy," *Biodemography and Social Biology*, 2011, *57* (2), pp. 171–183.

World Bank, "World Bank Open Data," Available online: http://data.worldbank.org/. Retrieved August 22, 2016 2016.

Zenou, Yves, "Job search and mobility in developing countries. Theory and policy implications," *Journal of development economics*, 2008, *86* (2), 336–355.

Appendix A

Overview, Design concepts and Details

In this appendix we present the *Overview, Design concepts and Details* protocol proposed by Grimm et al. (2006) and updated in Grimm et al. (2010). The main purpose of this protocol is to present agent-based model is the most standardised way possible. This also helps other researchers reproduce the model partially of completely. The *Overview* section of the protocol provides a general idea of the model, without going into all the details. In the *Design concepts* the model is described through a series of typical characteristics such as emergence, stochasticity and interaction. Finally, the third part called *Details* contains all the details of the model and resembles the most a standard description of an economic model.

A.1 Overview

A.1.1 Purpose

The purpose of this agent-based model is to study the effects of changes in the tax- and social security schemes in Mexico on economic growth, inequality and intergenerational social mobility. In particular, we aim at studying the effects of a universal social security as compared to the currently implemented dual system where formal workers have access to a much completer social security system as opposed to informal workers.

To achieve the goal, the model has to include a variety of processes, actors and phenomena. In particular, we focus on (investment in) education, the labour market and goods and services market. Additionally, we also include phenomena related to social mobility such as assortative mating, education dependent fertility, indivisibility of education, public vs. private schooling, etc. The model is based both on traditional modelling ideas from economic theory and empirical evidence.

The key agents in the model are families, firms and to a lesser extent the government.

A.1.2 Entities, state variables and scales

The model is composed of four explicitly modelled entities: firms, individuals, families and the government. Other entities such as the health, education and finance sector are modelled implicitly through methods. They do not have any kind of state variables.

Table A.1 presents the four main entities along with their state variables. In brackets we indicate the scale or type of each of the state variables.

Time frame

The time unit in the model is one year. The reason for this choice is that many important decisions are taken annually. In particular, each year students either pass a grade or not and parents have to decide whether or not to send children to the next level. Governments generally also publish their statistics on an annual basis, thus it makes sense to model the world for this time unit. Furthermore, using a year as unit rather than a longer period will allow us to analyse the short-, medium- and long run effects of the policy changes.

Table A.1: Main entities

Entity	Firms	Families	Individuals	Government
Role in the model	Producing goods, employing workers, pay taxes and social security contributions	Consume, invest in education and health, work and invest	Work, study	Collect taxes, finance services and consume
Groups lower level entities	Yes, individuals as workers	Yes, individuals as family members	No	No
State variables	Constants **Product type** [category] Dynamic **Workers** [Individuals] **Formal** [Binary indicator] **Capital** [numeric] **Equity** [numeric] **Owner** [Family] **Production** [numeric] **Profit Ratio** [numeric]	Constants **Father** [Individual] **Mother** [Individual] **Preferences** [parameters] Dynamic **Children** [Individuals] **Savings** [numeric] **Family business** [Firm]	Constants **Gender** [binary] **IQ** [numeric] **Mother** [Individual] **Father** [Individual] Dynamic **Age** [numeric] **Years of education** [numeric] **# failed grades** [numeric] **Human capital** [numeric] **Health stock** [numeric] **Reservation wage** [numeric] **# of children** [numeric] **Partner** [Individual] **Life status** [categorical] **Enrolled** [Binary] **Private school** [Binary] **Working** [Binary] **Total labour experience** [numeric] **Formal labour experience** [numeric] **Married** [Binary] **Retired** [Binary]	Dynamic **Income tax** [numeric] **Corporate income tax** [numeric] **Value added tax** [numeric] **Social security contributions** [numeric] **Health care expenditure (CSS)** [numeric] **Health care expenditure (NCSS)** [numeric] **Expenditures for pensions (CSS)** [numeric] **Debt level** [numeric]

A.1.3 Process overview and scheduling

Table A.2 outlines the scheduling of each process taking place in each period. The column priority refers to the order (starting with the highest).

Table A.2: Overview of processes and scheduling

Priority	Entity	Process/Explanation
100	Model*	1. Cleans internal data (e.g. statistics) at the beginning of each run. 2. Copies the parameters to the class Agent.
90	Family	1. Procreation 2. Ensure that not all members of the family are enrolled
85	Individual	1. Makes each individual one year older 2. Simulates the health shocks (and death) 2.1 If death of last parent: Split of families and bequest 3. Grade passing of enrolled students 4. Update of life status 5. Mating process
80	Family	1. Removes dead people and families 2. Families receive interest on savings
79	Firm	Firms analyse the situation and decide if they want to hire or fire workers if hire: creates job offers if fire: removes worker form firm and set to unemployed
77	Family	People search jobs and postulate for interesting vacancies (wage above reservation wage)
75	Model*	Firms loop though all job offers and select the best candidate for each job offer. Job offers are sorted in a way to ensure that individuals always get their first best job if it is offered to them.
72	Firm	Firms produce the goods, pay social security contributions and income taxes for workers (if formal), pay corporate income tax, pay salaries to workers, depreciate their capital, send excessive profit to their owners
71	Model*	Computes the profit ratio for all types of firms
60	Family	1.1 Family consumption decision and actual consumption 1.2 Families with a lot of savings are eligible to create a new firm
55	Government	The government computes its total income and spends the money on health care and pensions according to the needs. The remaining money is used for government spending according to a fix proportion of each good.
20	Agent*	1. Adapt prices in case of being off equilibrium 2. Update of some population statistics (e.g. average salary per education level)
1	Model*	Export of data for posterior statistical analysis

* = the entities *Agent* and *Model* are auxiliary classes in the implementation. They have no economic meaning and are used to ensure a smooth and efficient simulation of the model.
Priority: the column priority indicates the scheduling, where methods with higher numbers are executed first. It is an ordinal variable, where the different values and the gaps between the values have no meaning.

The order in which the different instances of each entity execute their processes is randomised in each period (tick). This ensures that the order does not influence the result.

A.2 Design Concepts

A.2.1 Basic principles

Families and firms are the key actors in this model, as they take important decisions in each period.

Families use a utility function to decide how much to consume, how much to invest in health, how much to invest in education and how much money to save to the next period. This optimisation process is influenced by the economic situation, for instance by the expected future income by education level. Furthermore, the family indirectly decides on the labour market participation of the children by not letting them to continue at school for instance. The schooling decision is a direct result of the optimisation process. Once children are out of school, they aim at incorporating in the labour market, thus there is not voluntary inactivity in this model.

Firms aim at maximising their profits by adjusting their production in terms of capital, labour and inputs. Depending on the product the firm produces, the marginal utility of the different types of labour is different. We assume that firms are price takers.

A.2.2 Emergence

In this model, most results emerge from the various interactions between the different players. Only a few results are directly imposed by the modelling approach. The most important results **emerging** from the model are:

- distribution of education
- income distribution
- age distribution and the health status of the population
- families (as a result partner search and procreation)
- distribution of firms and their respective production
- wage structure in the economy
- formality of firms

In contrast, a few results are **imposed** by static processes:

- intergenerational IQ correlation
- spousal correlations in terms of education and IQ
- relationship between maternal education and IQ and the number of children

A.2.3 Adaptation

Families adapt their consumption and investment (in health and education) to their current economic situation and the education investment to the current economic environment (expected returns to education).
Firms adapt their productive structure to the price structure in the economy and the availability of labour.
The prices of the goods are adapted in case the demand and the supply are substantially different from each other. This is simply implemented to have a reasonable relationship between supply and demand. The small open economy assumption does not require supply to be equal to demand.

A.2.4 Objectives

The objective of firms is to maximise their profit, while the objective of families is to maximise the family utility function. Individuals have no objectives apart from the family level objectives.

A.2.5 Learning

Firms can only observe generally observable characteristics of potential workers (e.g. years of education, experience), but not their actual level of human capital. Once the worker is employed, the firm has a better understanding of the human capital.

Families do not directly observe the ability level of their children but can indirectly learn about it by observing the number of times a student failed to pass a grade.

A.2.6 Prediction

Families and firms do not predict the future over several periods. Instead, they take the current values as a good estimation of the future periods. In this sense, education decisions are affected by the average wage by education. Families also predict their income in the next period based on their decisions today (e.g. whether or not the children continue at school) and taking the income level of the current period as an estimate for the next period.
Firms optimise their productive structure based on the current price level.

A.2.7 Sensing

Families know the health status of each family member and learn about the ability level of children through the number of failed grades. Firms learn about the actual human capital of workers (as opposed to the generally observed level of years of education.

A.2.8 Interaction

The only direct interactions between agents take place in the labour market and the marriage market. Both processes are similar in the sense that agents try to find the best match for their purpose.

In addition to these direct interactions, many indirect interactions through the economy take place. For instance, families take economy-wide indicators (e.g. wage level per education) into consideration when they decide on the enrolment of children. These economy-wide values are of course the results of all the interactions in the model.

A.2.9 Stochasticity

The model has a series of stochastic elements. Upon initialisation, the initial population is randomly drawn from a larger population stemming from the Mexican Family Life Survey. The randomisation is carried out at the family level in order not to manipulate the actual family structures.

During the simulation, several processes have stochastic elements. In most cases the probabilities depend on deterministic processes, but the actual choice then takes place using a stochastic process.

Procreation	In each period a couple will procreate with a certain probability. This probability is based on the age and education of the woman.

Health shocks	In each period, individual face a risks of a health shock. The probability and the intensity of the shock are stochastic, but depend on the age and previous health stock of the individual.
Human capital accumulation	For enrolled students the human capital accumulation depends on their IQ, their health status and a stochastic element.
Mating process	The partner mating process is based on a probability of mating with other individuals that depend on the differences in terms of education and IQ of the two individuals. The actual partner is then chosen stochastically among all candidates with a positive probability
Labour market	Potential workers cannot see all job offers in the market. The probability of seeing a particular job offer depends on their current labour status, their network and their type of education (public vs. private).

All stochastic elements can be steered through a unique random seed, allowing us to reproduce the exact same simulation multiple times and to base any type of policy analysis on the exact same random elements.

A.2.10 Collectives

We have two explicit collectives: firms and families.

Families naturally regroup all family members. Social ties are kept even when children leave their original family (e.g. for bequests). On the other hand, individuals that are working are regrouped in firms.

A.2.11 Observation

In each period various datasets are exported in a generic text format. These datasets include model-wide statistics such as income inequality, intergenerational correlations, but also instance-level data on firms, families, individuals and the government.

In batch simulations (multiple simultaneous simulations) independent datasets for each simulation are exported. These datasets can then be combined and the different parameter sets can be identified for the policy analysis.

A.3 Details

A.3.1 Initialisation

The simulation is initialised based on actual data from Mexico. We use the Mexican Family Life Survey (MxFLS) 2002 to generate a dataset of 27'455 individuals from 7'020 families. For each family member we have information on their cognitive ability (an approximation of their IQ), their current education level in years of education, their role in the family (father, mother, child), their gender, age and for enrolled children the type of school they are attending (private vs. public).

Unfortunately the Mexican Family Life Survey does not allow us to get usable information on their financial situation. We therefore randomly draw the initial savings of the families and define families with a certain level of savings and at least one member with secondary education or more as eligible for having a family business. These firms are then randomly assigned to all eligible families. Workers are allocated randomly to firms according to their education level.

Apart from the generation of our population, we set some initial values that are needed in the economy. For instance, the initial prices of the goods were selected based on preliminary results where the prices converged to certain levels. We took these levels to initialise the model.

The salary paid by education level was estimated using the Mexican Labour Force Survey and we then converted all to multiples of the annual minimum salary (the monetary unit we use in the model).

The tuition fees for schooling were estimated from various sources of information and we always use the same values in all simulation in order not to manipulate the outcomes.

Finally, all simulations are always initiated with the actual rates (taxes, social security, etc.) observed in Mexico. When we simulate policy changes, we always simulate the baseline model for 25 period before starting with the policy changes.

A.3.2 Input

We do not use inputs during the simulation.

A.3.3 Sub-models

In this last section of the ODD-protocol we present the sub-models. In other words, we describe the various processes included in this model. We organise this section by type of agent. This ordering is in some cases not very simple due to the strong interactions between agents.

A.3.3.1 Firms, production and labour market

A.3.3.1.1 Product and firm space

Our model is based on a four-sector economy with both formal and informal and small and big firms. Figure A.1 displays both the firm and the product space of our economy.

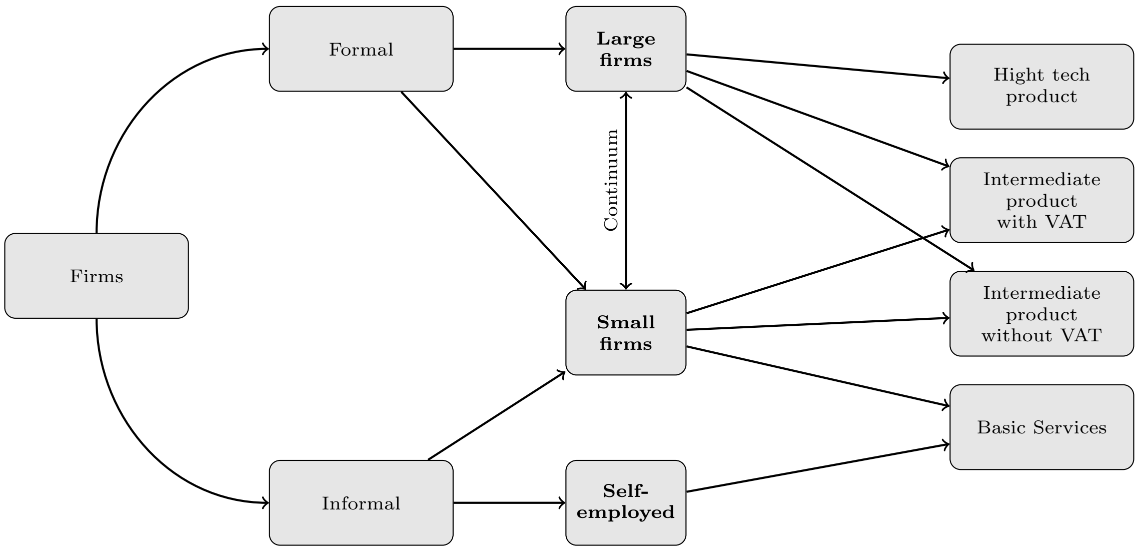
In the firm space we have small self-employed individuals which are always informal. For larger firms we then have a continuum from small to large firms, where the actual firm size is endogenous to the optimisation of the firms. These firms can be either informal (typically the smaller ones) or formal. The choice between informal and formal will be made endogenously by the firms and can change over time (e.g. an informal firm becomes formal).

In the product space we have exactly four types of products, similar to the product space in Antón et al. (2012). The basic product refers to very simple services and products that need no or very limited capital (e.g. taco stand). The two intermediate products already require some capital for the production and the only difference among them is that one is subject to VAT while the other is not[1]. Finally, we have a high-tech product, which can only be produced by relatively large formal firms!

It is important to mention that the firm size is endogenous and emerges from the optimisation of firms. We do not impose any size restrictions.

[1]This is a feature of the current Mexican tax system, where a series of not very sophisticated products is taxed at a reduced VAT rate. This reduced rate is currently set to zero.

Figure A.1: Product and firm space



A.3.3.1.2 Production function

Similar to the model proposed by Antón et al. (2012), our economy has a limited number of products, which are all produced by firms using a common production function. Of course, the parameters of this function vary across the products. As inputs of the production function we have different elements:

1. **Labour**: here we distinguish the labour by educational level. For more complex products a larger share of highly educated workers is required.
2. **Capital**: for the production function we simply consider the sum of both private and market based capital.
3. **Intermediate products**: all product may or may not be used in the production of another product. Typically, simpler products are used for the elaboration of the most complex product, while the opposite is not true.

The production function can be formally written as:

$$y_p = f(K, L, y_{-p}) = K^{\beta_K} \prod_{i=0}^{4} L_e^{\beta_{Le}} \prod_{p=1}^{3} y_p^{\beta_{y}p} \tag{A.1}$$

where K is capital, L_e labour of education level e and y_p are all the other products that can be used as inputs. We assume constant returns to scale by setting $\sum \beta = 1$. L_e refers to the effective productivity of labour per educational level (none, primary, lower secondary, upper secondary, tertiary) and not to the simple number of workers. This distinction is important as we do not impose the same productivity to each worker.

The following table displays the parameters we are using in our baseline model:

Parameter	**Symbol**	**Basic good**	**Inter-mediate 1**	**Inter-mediate 2**	**High-tech product**
Capital	β_K	0.1	0.1	0.1	0.3
Labour: no education	β_{L0}	0.9	0.05	0.05	0.03
Labour: primary	β_{L1}	0	0.10	0.10	0.05
Labour: lower second.	β_{L2}	0	0.20	0.20	0.10
Labour: upper second.	β_{L3}	0	0.15	0.15	0.12
Labour: tertiary	β_{L4}	0	0.1	0.1	0.10
Input: basic good	β_{y0}	0	0.1	0.1	0
Input: Intermediate 1	β_{y1}	0	0	0.2	0.15
Input: Intermediate 2	β_{y2}	0	0.2	0	0.15

We can see that both intermediate goods are identical in terms of their production function. They both use the respective other intermediate good and the basic good as input. The high-tech good then uses only the two intermediate goods as input. Given the constant returns to scale assumption, all columns in the table sum up to 1, making comparison of the value across columns unreasonable. What truly matters is the relative importance of the parameters within a column. For instance, workers with tertiary education have the same parameter for all but the basic good. However, for the final good compared to the intermediate goods, this type of education is relatively more important than lower levels of education.

Also note that the different labour levels refer to the requirements. Of course, a higher educated individual can be hired as non-skilled worker, but then only a part of his or her human capital can actually be used.

A.3.3.1.3 Effective labour productivity

The effective productivity of each worker depends on three key elements: human capital, health and on-the-job-training (experience).

We can formalise this using the following equation:

$$ELP_i = HC_i \times OJT(\mathit{TotalExperience}, \mathit{FormalExperience}) \times HS \tag{A.2}$$

where OJT refers to on-job-training, which is a function of both formal (f) and total experience (e), which is the sum of formal and informal labour experience. We use a simple functional form:

$$OJT(f, e) = 1 + \gamma_f \sqrt{f} + \gamma_e \sqrt{e - f} \tag{A.3}$$

with parameters $\gamma_f > \gamma_f$ ensuring that work experience in the formal market increases labour productivity more than experience in the informal sector. The reasoning behind this notion of effective labour market productivity is that all three factors play a role in determining how effective a worker is. The core element here is human capital, which takes values from zero to 16 (years required for tertiary education). The other two elements have neutral values of unity, thus having a less than perfect health reduced the productivity and having a positive amount of experience increases the productivity at decreasing rates.

A.3.3.1.4 Profit maximisation

A key decision for firms is to have the best possible combination of labour (L), capital (K) and intermediate products (y_{pt}) in their production function in order to maximise their profits. In our model, the information set firms can use to decide is limited to their own experience (e.g. no strategic behaviour on expected moves of competitors).

In each period, informal firms also evaluate if it would be beneficial to become formal. For these calculations, firms consider the market values of the current period as their best guess for the future periods. First, firms compute the optimal production for different labour force structures

$$y_{pt} = f_p(K_t, L_t, y_{-p}) \tag{A.4}$$

Technically this optimisation is implemented in a two step procedure. We loop over different possibilities to hire and fire workers and for each given case we compute the conditionally optimal levels of K and y_{-p}. Each of these production levels are then multiplied by the price of the product to get the gross income and the profit is computed using the following equation:

$$\Pi = \begin{cases} (1 - \pi_{CIT}) \left(\frac{y_{pt} p_{pt}}{1 + \pi_{VAT}} - c_f(K_t, L_t, y_{pt}) \right) & \text{if formal} \\ y_{pt} p_{pt} - c_i(K_t, L_t, y_{pt}) - E[\Theta] & \text{if informal} \end{cases} \tag{A.5}$$

where

$E[\Theta]$ is the expected amount of fine in case the government catches the informal firm:

$$E[\Theta] = \sum w \times \theta_p \times \theta_m$$

with $\sum w$ being the sum of all wages paid by the firm (e.g. firm size), θ_p the probability of getting caught and a parameter for the size of the fine θ_m. We include the sum of wages to capture a higher risk for larger firms.

$c_i(.)$ and $c_f(.)$ are the cost functions for informal and formal firms respectively. They differ in several ways according to the formality status. Informal firms do not pay the contributory social security and do not deduce the income tax of their workers. In contrast, formal firms can buy input goods without paying the value-added tax (they get refunded), but pay the previously mentioned contributions and taxes.

π_{CIT} is the corporate income tax rate, which if only relevant for formal firms

In section A.3.3.4.2 we provide a detailed discussion on the actual tax schemes in Mexico and how we implement it in the model. This also includes a discussion on the social security contributions.

Note that firms cannot adjust completely, because at least a part of the capital cannot be destroyed from one period to the next. We therefore include parameter $\delta_{capital}$ capturing how much a firm can reduce the capital stock from one period to the next. Furthermore, we distinguish equity from market capital. Equity is the capital the owner family has invested in the firm, while market capital a loans from the financial market. We use a parameter $\delta_{leverage}$ to limit the market capital vs. equity ratio. Whenever the firm's optimal choice is to reduce the capital, it first reduces the market capital. If this is not possible, the firm reduces equity by sending the excessive money to the owner. In an equilibrium condition where the optimal capital remains stable, the owner will receive the benefits of the firm in each period.

A.3.3.1.5 Labour market

The labour market is organised in three steps:

1. Firms analyse their current situation and create one or multiple job offers if this increases their expected benefit for the next period. A job offer consists of a minimum education level and a wage offer. In case firing workers is beneficial in terms of expected benefit, firms immediately remove the worker from the labour force.
2. Individuals see these job offers with a certain probability and apply if and only if they qualify for the job and if the offered wage is above their reservation wage.
3. The firm chooses the best candidate among all applicants.

We now explain each of the steps individually.

Step 1 - Firms create job offers

First, firms optimise their labour stucture according to the profit maximisation described in section A.3.3.1.4. Depending on the result of the optimisation process, the firm dismisses current workers and/or opens a new job vacancy. At this stage it is important to mention that firms optimise assuming they find an average worker with the profile they search for. However, firms cannot observe all characteristics of workers and might not find exactly what they were looking for. Job vacancies are translated into job offers that include information on the minimum education level and the offered wage. For simplicity, we assume that within a firm workers with the same education level all earn the same salary. Hence, the proposed salary is simply the salary that is already being paid to other workers in the firm.

Step 2 - Job seekers apply to interesting jobs (labour supply)

Each job seeker received a given job offer with a certain probability p. This probability varies across individuals and depends essentially on:

- Labour status: unemployed job seekers have a higher probability than currently employed job seekers (argument: they have more time to search).
- People with better networks have higher probabilities of receiving the job offer. These networks can be private (family members working in the same firm), professional (offers of similar firms have higher probabilities) or educational (graduates of private schools might have higher probabilities).

Hence, the final probability of seeing a job offer depends on all these elements.

$$p = p_{base} + p_{unemployment} + p_{network} + p_{privateSchool} \tag{A.6}$$

Individuals will then apply to all job offers for which they qualify (education weakly above the requested level) and where their reservation wage ($\underline{\mathrm{w}}_i$) is below the offered wage. The reservation wage is defined as:

$$\underline{\mathrm{w}}_i = \max\left(w_{independent},\ \mu_w \times E[w|educ_i]\right) \tag{A.7}$$

which is essentially what the individual could earn as independent and a fraction of the average wage given the education level. The parameter μ_w captures how tolerant an individual is to offers below the current average of individuals with the same level of education.

Step 3 - Firms choose the best candidate

The final step in the job market is when firms choose among all the candidates. In case of having zero candidates, the vacancy remains and nobody is hired. Whenever there is a positive number of applicants, the firm chooses the best candidate according to the following list of priorities:

1. The candidate with the highest level of education
2. if there is a draw: candidate with the largest experience in the formal sector
3. if there is still a draw: candidate with the largest total experience
4. if there is still a draw: candidate with more diploma from private schools
5. if there is still a draw: random

Note that before looping through all firms, we order the job offers starting with the highest offered wage. This ensures that candidates will always get their first best option (if the firm is interested) and do not have to accept the first they receive. In case the firm is unable to find a worker for a given position, it increases the salaries of the concerned education level by 5% for the next period.

A.3.3.1.6 Capital depreciation

Every year (period), the capital of the firm is depreciated by a depreciation factor of δ_d. Given that the market capital is what the firm owes the lenders, the depreciation is accounted for on the equity side only. For instance, a firm with 20 units of equity and 80 units of debt, will have a depreciation of 5 units. Hence, after depreciation, the equity become 15 units.

A.3.3.2 Financial market

The financial market is implemented in the simplest possible way. We use exogenously set interest rates for both loans to firms and on savings by families.

A.3.3.3 Family related processes

A.3.3.3.1 Optimisation of allocation of resources

Families optimise behaviour by choosing among current consumption, investment in health and education and saving money for the next period. There is no possibility to borrow money. The decision is governed by a rather traditional utility maximising approach based on the strand of literature initiated by Becker (1973). However, due to the time unit of one year, the decision making process has to be slightly adapted.

Let us define the general utility function as:

$$U(c_t, H_t, E[y_c], E[m_{t+1}]) \tag{A.8}$$

Where:

c_t	is the per capita expenditure for current consumption in period t. This consumption is further divided into the consumption of the four goods that are produced in the economy. We will explain the details hereafter.
H_t	is the average health stock of all family members. The idea here is that people directly care about the health status of the family members and therefore aim at maximising this value. In case all members of the family are in perfect health ($H_{it} = 1$), no spending for health care is required.
$E[y_c]$	is the average expected future incomes of the children. This values can be manipulated by family through investment in education.
$E[m_{t+1}]$	is the expected future disposable income in period $t+1$. Here the idea is that instead of a life-time maximisation, people simply care about what they will have one period ahead. In our view, this approach does comply with the basic ideas of the traditional economic models while not relying on the rather unrealistic idea that people plan ahead over the whole lifespan.

In this version of the study, we use a traditional Cobb-Douglas function:

$$U(c_t, H_t, E[y_c], E[m_{t+1}]) = c_t^{\alpha_c} \times H_t^{\alpha_h} \times E[y_c]^{\alpha_y} \times E[m_{t+1}]^{\alpha_m} \tag{A.9}$$

This functional form allows us to easily decompose the element of current consumption:

$$c_t^{\alpha_c} = \left(\prod_{p=0}^{3} c_{pt}^{\alpha_{cp}} \right)^{\alpha_c} \qquad \text{with} \sum_{p=0}^{3} \alpha_{cp} = 1 \tag{A.10}$$

As a result, we can interpret c_t as a measure of expenditure in consumption good. The exact consumption of the four goods is then governed by the parameters α_{cp}.

Note that we also include a parameter governing the ability of a family to reduce consumption from one period to the next. It is unreasonable to assume that a family can reduce the consumption by a very large amount. Therefore, we assume that family tolerate only a loss of τ_{exp} and in case of having less disposable income, the family starts dropping children in out of private schools or even completely out of school and ask them to work as independent.

Numerical optimisation in the ABM model

Similar to the optimisation of the profit function for firms, we solve this optimisation problem partially analitically and partially numerically. First, we use all the properties of the Cobb-Douglas function to express one optimal value in function of another optimal value. We then loop over all possible combinations of discrete choices (school enrollment) and optimise numerically using a Java implementation of the *Constrained Optimization BY Linear Approximation*[2]. Thanks to the loop of discrete choices and the properties of the Cobb-Douglas function, this numerical optimisation is one-dimensional. This greatly reduces the computation.

A.3.3.3.2 Families starting a business

Whenever family have savings exceeding a certain threshold $\delta_{business}$, they are eligible to start a new business with a certain probability. The process is implemented in a very simple way by looking at the average profit ratios

[2]The code of this optimisation is available at: https://github.com/cureos/jcobyla

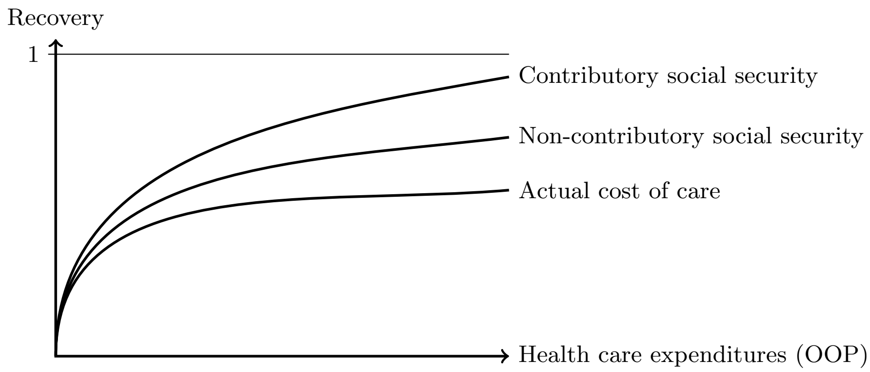
of each type of firms. All firm types where the average profit ratio is above the interest rate on savings, are eligible to be created. Families then randomly start a firm producing one of these eligible goods. Technically the firm is created in period t and the starts operation in $t+1$ with a optimisation of the labour force.

A.3.3.3.3 Health recovery and health stock

In each period individuals might suffer health shocks which negatively affect their health status. The health status is defined on the interval between zero (death) and one (perfect health) similar to the definition the health stock in the traditional Grossman model (Grossman, 1972).

For any level below unity of the health stock, individuals can invest in health care services to recover their full health stock. In our model, we mimic the dual health care system in Mexico, where formal workers have access to the full-fledged services of the contributory health care system (CSS), while informal workers have only access to the non-contributory health care system (NCSS) with limited services[3]. The fundamental difference from the patients perspective is that health care in the CSS is almost for free, while the out-of-pocket (OOP) expenditures are higher in the NCSS. We use this feature to implement the dual health care system in a very simple way. Figure A.2 depicts schematically the implementation idea.

Figure A.2: Recovery from health care shock



The figure highlights several important issues. First, the marginal return on investment in health care is substantially larger for small investments. The rationale behind this is that recovering from a minor health condition is relatively cheap and very cost effective, while severe health conditions (e.g. cancer) require a substantial investment for recovery.

A second point is the difference between the two curves, where the NCSS is always below the CSS curve. This suggest that for a given level of recovery the out-of-pocket investment in the NCSS is higher compared to the CSS.

Mathematically, we implement this idea using a squared root specification:

$$\text{recovery} = \begin{cases} \min(1, \eta_{CSS} \times \sqrt{hce}) & \text{if CSS} \\ \min(1, \eta_{NCSS} \times \sqrt{hce}) & \text{if NCSS} \end{cases} \tag{A.11}$$

where η_{CSS} and η_{NCSS} are two parameters for the contributory and the non-contributory social security respectively. In the baseline model we use the values of $\eta_{CSS} = 0.9$ and $\eta_{NCSS} = 0.45$, suggesting that a full recovery

[3]It could be argued that the private health care sector is a third system in Mexico. In the current version of our model we do not include this possibility.

requires roughly 1.23 annual minimum salaries in the CSS and slightly below 5 annual minimum salaries in the NCSS.

Finally, we also assume the total cost of care to have a similar functional form. The curve of the actual cost lies below the out-of-pocket expenditure curves. For a given level of recovery, the horizontal difference between the lines refers to the cost for the social security system. We assume that the cost of producing a certain level of recovery is the same in both systems and the only difference is the share of out-of-pocket expenditure.

A.3.3.3.4 Bequest and dissolution of family

A family is conformed with parents and an endogenous number of sons and daughters. When both parents die, the family is split into single individual families (i.e. each child becomes a new family). Moreover, each of them receive a bequest, which is equal to a part of savings and equity of the former family. While savings can easily be split, equity refers to the investment in the family company and can therefore not be split in our model.

In our model, only one child will inherit the family's company, this assignation is random. This assumption could yield unequal inheritance for children (e.g. some son receive more (or less) valuable bequests only because they could not split the company symmetric parts). In order to ensure equality in the process, we use the following logic:

1. We sum savings and equity together and divide it by the number of children. We then have two scenarios:

2.a If equity is less or equal to the share of each child, we randomly select one child who gets the business plus any cash from savings to achieve the equal share.

2.b If equity exceeds the equal share, the firm sells equity (e.g. replaces equity by external investment in the firm) until the equity of the firm equals the equal share. The money obtained from selling equity will be distributed among the siblings not receiving the business.

A.3.3.3.5 Passing a grade at school

Human capital accumulation is a cumulative process during which each school year adds some human capital to the already acquired human capital stock. We use this general idea to implement the human capital accumulation process in our model.

We define 1 unit of HC as being the equivalent of 1 year of perfect (best possible quality) schooling. Hence, we have by definition

$$\text{human capital } (HC_i) \leq \text{years of schooling}_i \tag{A.12}$$

$HC \leq years of schooling$ by definition.

In each period while being at school, children add a certain level of human capital to their previously acquired level of human capital:

The process of passing a grade is simulated in various steps:

$$HC_{it} = HC_{i,t-1} + \min(1, \frac{IQ}{100} * HS_{it} + \epsilon_{it}) \tag{A.13}$$

where IQ refers to the cognitive ability measure and HS_{it} is the health stock of the individual. Therefore, the expected additional human capital of an average child (IQ=100) in perfect health is equal to unity. The element ϵ_{it} is a stochastic process which captures some heterogeneity in the human capital accumulation process.

Similar to what happens in the real world, student progress to the next grade only if they pass a certain threshold. We define this threshold as a fraction of the years of schooling. For instance, to pass the fourth grade, the accumulated human capital must be at least $\delta \times 4$, where we typically have $\delta \leq 1$. This yields a simple passing rule:

$$HC_{it} \begin{cases} \geq \delta \times g & \text{passes grade } g \\ < \delta \times g & \text{has to repeat grade } g \end{cases} \tag{A.14}$$

This implementation is interesting for a number of reasons:

- The human capital accumulation process is cumulative, thus a low accumulation in the past (e.g. due to a low health stock) will have long lasting effects.
- the requirements to pass grades can change from one level of schooling to another (e.g. $\delta_{primary} < \delta_{secondary}$). The consequence of this would be that children who just passed primary on the threshold, will have a hard time passing the first grade of the next school level. In the baseline model we use respectively 0.8, 0.85, 0.90 and 0.95 for primary, lower secondary, upper secondary and tertiary education.

In case of not passing the grade, we do not add the full level of human capital to capture the fact that repeating the grade does not increase knowledge in the same way as continuing with the next grade. In contrast, adding a part of the acquired human capital rather than nothing captures the fact that even if students did not pass the grade, they have learned something and the likelihood to pass the grade one year later is substantially higher.

A.3.3.3.6 Mating process - assortative mating

The mating process in our model takes place in three majors steps: selection of candidates, computation of probabilities and actual selection of partner.

Step 1: Selection of eligible candidates

In a first step, eligible individuals start searching all eligible candidates. Eligibility is based on four criteria:

1. the searcher and the possible candidates are not currently enrolled at school
2. both have currently no partner
3. both are weakly older than the minimum mating age ($\delta_{minAge} = 15$)
4. the potential partner must be of the opposite sex

Step 2: compute the mating probability

For all possible candidates the mating probability is computed. This is the crucial step to achieve a certain degree of assortative mating. We assume the following form:

$$P_{ij} = \max\left(0\ , 1 - \frac{\Delta_{ij}^{IQ}}{30} - \frac{\Delta_{ij}^{educ}}{6}\right) \tag{A.15}$$

where $\Delta_{ij}^{IQ} = |IQ_i - IQ_j|$ and $\Delta_{ij}^{educ} = |eudc_i - educ_j|$ are the absolute values of the difference between the two individuals in terms of IQ and education.

Note that the probability is equal to zero whenever the IQ-difference exceeds 30 points or the education difference exceeds 6 years. This implementation is an improved version of the implementation proposed by Chávez-Juárez (2015). In this version individuals that are more alike have a higher mating probability.

Step 3: Compute overall probability

Before drawing the stochastic element, we then normalise these probabilities by dividing all of them by the sum of all probabilities and by multiplying by the overall probability of mating.

$$p_{ij}^n = \frac{P_{ij}}{\sum_j P_{ij}} \times p_{mating} \tag{A.16}$$

we then draw a random number from a uniform distribution and select the corresponding partner. Note that with probability $1 - p_{mating}$ no match takes place. In this case, individual i will start again searching a partner in the next period.

In case of a positive match, the two individuals leave their family and create a new family.

A.3.3.4 Government related processes

A.3.3.4.1 Government behaviour

The government has a rather simple behaviour, but the different elements are crucial for the model. First, the government sums up all the incomes from the social security contributions, the value-added tax and the income taxes and deduces the debt from the last period if there was any. This gives us the total disposable money of the government. We then deduce the pensions paid to retired workers of the contributory social security system, assuming 60% of the last salary as a pension payment. We then deduce the cost of health care according to both systems.

If after these deductions a positive amount of money remains, the government will consume goods and services. We assume that the government mainly spends on intermediate (20% each) and high-tech (45%) products and only 15% of the spending goes to the basic good. These proportions do not seem to be of much importance for the stability of the model.

In order to ensure a certain degree of stability, we assume that the government spending cannot be reduced by more than 30% from one period to the next. Hence, if the government does not have a sufficient amount of money to spend at least 70% of the last years spending, it has to borrow money. This mechanism is of course very simplistic, but when we simulate the model is happens only rarely and the results do not depend on it.

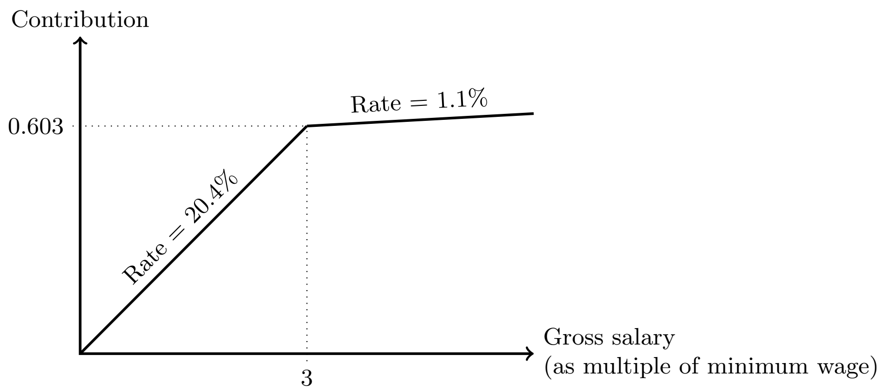
A.3.3.4.2 Tax schemes and contributory social security scheme The different tax schemes are directly inspired and where possible copied from the actual Mexican tax system.

Social security contributions

In reality, the social security contributions are based on a rather complex computation with various categories of contributions (by concepts). We opted for a simplification of the process that will capture the important elements of the true system without adding unnecessary complexity to the model. This simplification is particularly important because our policy simulations will target these contributions and therefore it is important to limit the complexity to the necessary level. A crucial characteristic of the social security contribution computation is its strong non-linearity at three minimum salaries. The contribution paid on the first three minimum salaries is 20.4%, and then falls to 1.1% for the part of the salary that exceeds three minimum salaries.

Figure A.3 schematically represents the amount of social security contributions the firm has to pay as a function of the base salary.

Figure A.3: Amount of social security contribution



The important issue here is that the contribution is relatively more important for low wages, thus firms hiring more people with only a few years of education face a higher relative cost of formality.

Income taxes for workers

To model the income tax of workers, we consulted the 2016 income tax rates. The system is based on brackets of income with the same increasing tax rate. Implementing this functional form one-to-one would imply the inclusion of roughly 20 parameters, which is of course not very sound for the modelling purpose. Therefore, we approximate the true tax rate through a polynomial regression of degree 2. The income tax is defined as:

$$IT = \max(0, -0.1303969 + 0.124559 \times income + 0.004959 \times income^2) \tag{A.17}$$

Up to around 1 minimum salary the tax rate is equal to zero in our model. This is a approximation of a substantially more complicated true system where individuals with low wages have a positive tax rate and at the same time receive subsidies.

As in the real world, income taxes for workers are directly paid by the firm through a deduction on pay day. Thus, workers of formal firms only receive their income net of taxes.

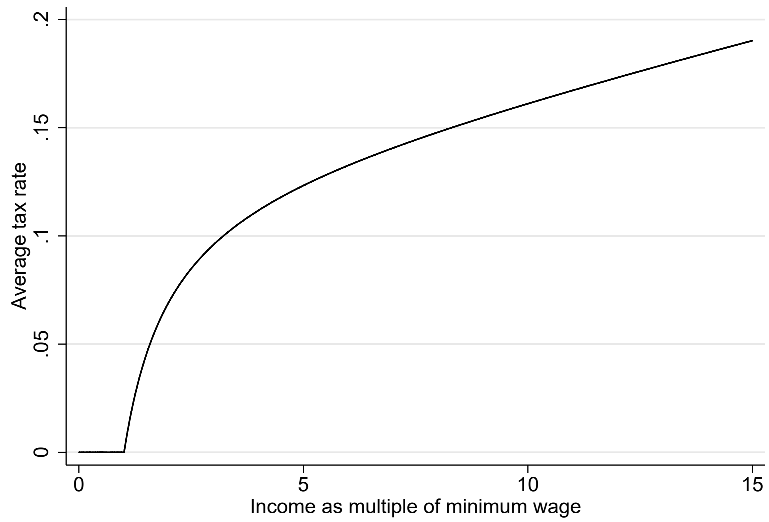
Value added tax

The value added tax in Mexico has generally two rates, the normal and the reduced rate. Currently, the reduced rate is set to 0%, resulting in an effective exemption from the VAT of these products. The regular rate is 16%. We directly use these rates in the baseline model and apply the regular rate to all but the intermediate good that is exempted.

Corporate income tax

The corporate income tax is applied to benefits of formal firms and the currently used value is 30%.

Figure A.4: Income tax rate in function of income



A.3.3.5 Nature and adaptation processes

We refer to nature essentially for processes that do not directly imply decisions made by agents or result from their interactions. In this regard, we have two processes that refer indeed to nature: health shocks and fertility. In addition we describe here the process of adaptation of prices in the goods and services market. Of course, this last process is not really a process of nature, but for the sake of our model, it is determined outside the bounderies of our economy.

A.3.3.5.1 Health shock

Health shocks are modelled randomly using a mixed distribution:

$$hs_{it} = \begin{cases} \sim exp(\lambda_{age}) & \text{with probability } p_{it}^{hs} \\ 0 & \text{with probability } 1 - p_{it}^{hs} \end{cases} \tag{A.18}$$

where p_{it}^{hs} is the likelihood of a health shock of individual i in period t. Conditional on having a health shock, this shock follows an exponential distribution with parameter λ_{age} and therefore the unconditional expected value of the health shock is $E[hs_{it}] = \frac{p_{it}^{hs}}{\lambda_{age}}$.

Now, it is important to explicitly define the two elements. We assume the probability of having a health shock to depend on age and the previous health stock. For age, it is relatively easy to obtain econometric estimates on the relationship between age and the extensive margin of health care spending. In contrast, it is much harder to estimate the relationship between the previous health status and the likelihood of a new health shock. We therefore estimate only the age relationship and assume a simple functional form with the health status. For this, we use the Mexican *Encuesta Nacional de Gastos y Ingresos de los Hogares (ENIGH)* 2012 where people are asked whether or not they had a health condition during the year. We then estimate a linear probability model against age in a polynomial functional for of degree 2. This estimation provides us with a conditional probability of having any health care shock given the age of the individual and provides us with the following functional form:

$$p_{it}^{hs} = (0.217 - 0.002 * age_{it} + 0.000063 age_{it}^2) + (1 - HS_{it}) \quad \text{(A.19)}$$

where the first part of the equation has been estimated using the ENIGH and the second element is a very simple implementation of the effect of the health stock. The idea here is that people with fragile health are more likely to suffer yet another health shock as compared to individuals in perfect health.

Conditional on having a health shock, the size of this shock only depends on the age. Here the logic is that a child might have more health shocks as compared to adults, but they are most of the time less severe. In contrast, for very old people every health shock might be potentially lethal. Therefore, we model the expected size of the health shock as a function of age:

$$E[hs_{it}|hs_{it} > 0] = \left[0.1 + \frac{6000}{age^2}\right]^{-1} = \lambda_{age}^{-1} \quad \text{(A.20)}$$

which produces relatively small shocks for young individuals[4] and potentially lethal shocks for the oldest members of society.

The calibration of these equations has been done indirectly by looking at the age structure of the initial population and finding parameters that reproduce this age structure over time. We are most likely overestimating slightly the size of the health shock for the oldest individuals. However, this is of little concern for this study because most of our key phenomena we look at refer to younger individuals having children and being active on the labour market.

A.3.3.5.2 Fertility

Fertility and especially the fertility gradient along the socio-economic distribution are important elements for social mobility. Nevertheless, our model focuses essentially on policy measures that are not likely to directly affect this behaviour and therefore we opt for a simple implementation (reduced form).

For this implementation, we use actual data from Mexico and estimate the likelihood of procreation for each woman in every period. In order to consider the socio-economic gradient of fertility, we estimate the likelihood by educational level of the mother.

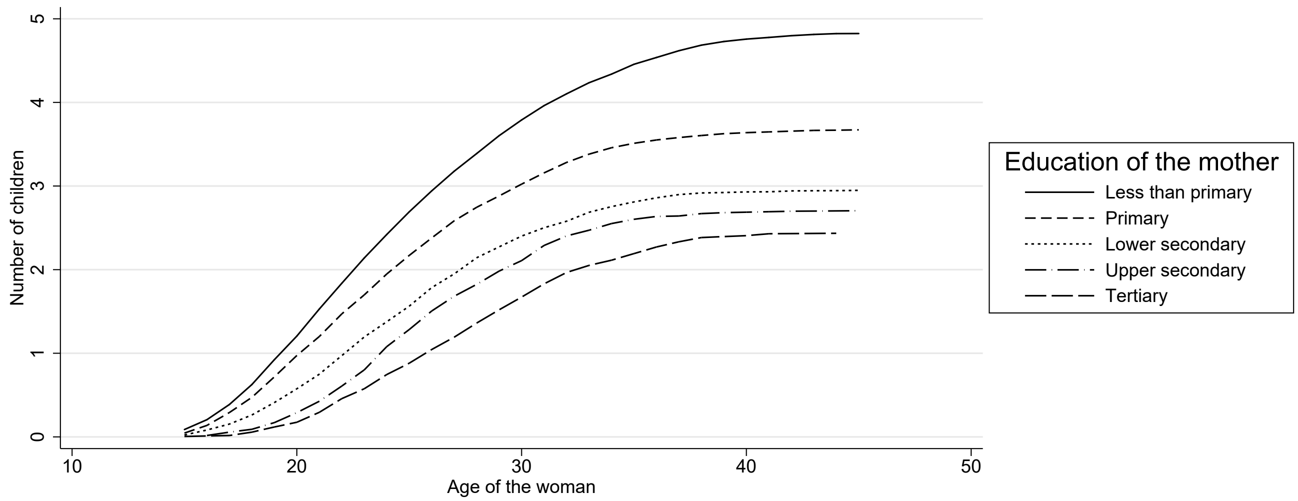
$$P(child|age) = \frac{\partial E[N_{children}|age, education]}{\partial age} \quad \text{(A.21)}$$

Figure A.5 shows the expected number of children in function of age and by education level of the mother. The estimates are based on data from the Mexican Family Life Survey (MxFLS) 2002 and considering only women in the age range between 15 and 45 years.

We can observe various differences across the curves. First, the expected number of children of poorly educated women is substantially higher than for women with tertiary education (around 4.8 children versus 2.2 children). Moreover, the more educated the woman is, the later she starts having offspring. In the model we convert these

[4] As an example, this equation produced $E[hs_{it}|hs_{it} > 0, age = 5] = 0.004$, $E[hs_{it}|hs_{it} > 0, age = 50] = 0.4$ and $E[hs_{it}|hs_{it} > 0, age = 80] = 0.96$

Figure A.5: Expected number of children by education and age



figures into probabilities of procreation at each age and use a stochastic process to define whether or not the woman has a child in a given period.

A.3.3.5.3 Adaptation of international prices

In Antón et al. (2012) the firms are price takers and prices are determined on the world market. Hence, they use a small open economy assumption. This implies that the domestic production need not be equal to domestic consumption. In general, we use this same approach[5], where firms first define their quantities (Q_S) given a certain price level. This price level can be for instance the price level of the previous period. Families then define the demanded quantity (Q_D) given that same price. This process does not necessarily yield an equilibrium condition in which $Q_S = Q_D$. This can be justified by imports and exports; thus we do not necessarily need a market clearing condition.

However, in order to avoid too large discrepancies between demand and supply, we adapt prices in function of the difference between Q_S and Q_D

Table A.4: Price adaptation in the goods and services market

If	**Then**
$Q_S > (1+\tau_1)Q_D$	$P_{t+1} = P_t \times \frac{Q_D}{Q_S}^{\tau_2}$
$Q_D > (1+\tau_1)Q_S$	$P_{t+1} = P_t \times \max(1.2, \frac{Q_D}{Q_S}^{\tau_2})$
Otherwise	$P_{t+1} = P_t$

where τ_1 is a parameter capturing the tolerance to supply-demand imbalances. For larger values of τ_1 we accept higher imbalances. By increasing this parameter, me might avoid some cyclical price behaviour. τ_2 is a parameter to shape the price changes. The value of 1.2 in the second row was included in the model in order to avoid too strong increases of the price. This limitations is generally not binding, but was necessary to for the model to run in

[5] A similar approach is also taken by Busso et al. (2012)

a few situations[6]. In general, the model results display only very little price changes and we do not expect major changes in the model results when not allowing prices to change over time.

[6]Most likely in the current version of the model this condition is no longer necessary, because the problem motivating us to add this condition has been solved during the programming process

Appendix B

Calibration

An important goal of our approach is to model as close as possible to reality, in this particular case to the Mexican economy. A crucial element in achieving this goal is the calibration of the model. Calibrating such model is, however, very complex because many different processes interact. For this first version of the model we used a mixed approach. Wherever possible, we used **Mexican data** or the **legislation** to calibrate parts of the model. This way of calibration is the first best solution, but unfortunately the data does not allow us to calibrate all processes in this way. The second best solution is the **indirect calibration**, where we look at the outcome of the baseline model and calibrate the model in a way to reproduce the result according to the observed results. For example, it is impossible to obtain estimates for the severity of health shocks, but we have knowledge about the age structure of the population. Thus, we calibrate the health shock in a way that the age structure emerging from the model resembles the actual age structure. Finally, the last calibration method we used is an **ad-hoc** definition of some parameters for which we do not have data nor a directly observable result. For all types of calibration, but especially for the last one, we use sensitivity analyses to see how much the results depend on such ad-hoc values. Table B.1 provides an overview of the used calibration method for the most important processes in the model.

Table B.1: Calibration methods

Process/value	**Type of value**	**Calibration strategy**
Taxes and contributions		
VAT rates	Parameters	From the Mexican law
Corporate income tax	Parameter	From the Mexican law
Income tax for natural persons	Parameter	Parametric approximation of actual tax scheme
Health		
Probability of health shock	Parameters	Mixed: relationship with age based on data (ENIGH), while the relationship with previous health stock was set ad-hoc.
Size of health shock	Parameter	Indirect based on the resulting age structure of the population.
Health recovery	Parameters	Ad-hoc

-continued on next page-

Table B.1: Calibration methods (*continued*)

Process/value	Type of value	Calibration strategy
Education		
Passing threshold	Parameters	Ad-hoc
Tuition fees	Parameters	Data: multiple sources for private schools. Ad-hoc for public schooling.
Labour market		
Reservation wage: tolerance to wage below average	Parameters	Ad-hoc
Initial wage levels	Initial values	Data: Mexican Labour Force Survey (see B.1)
Returns to labour experience	Parameters	Ad-hoc
Adjustment costs	Parameters	Ad-hoc and inspired by the law
Likelihood of seeing job offers	Parameters	Ad-hoc and indirect
Families and their behaviour		
Initial population	Initial values	Data: Mexican Family Life Survey 2002
Parameters of family utility function	Parameters	Ad-hoc and partially indirect.
Fertility	Parameters	Data (MxFLS 2002)
Firms and production		
Parameters of production function	Parameters	Indirect
Fine (amount and probability) for informal firms	Parameters	Ad-hoc
Price adjustments	Parameters	Ad-hoc

We would like to highlight that due to the tight schedule of the project, the calibration and the sensitivity analyses were done in best way possible. Having more time would allow us to take these two procedures a few step further and probably improve the adjustment of the model to the Mexican context.

B.1 Income

To initiate the model we assume a homogeneous wage level for each level of education. The starting values were obtained from the Mexican Labour Force Survey called *Encuesta Nacional de Ocupación y Empleo (ENOE)*. This nationally representative survey is a rotating panel, in which each participant is interviewed 5 consecutive quarters. We used five rounds of ENOE (2015Q1 through 2016Q1) to calculate average income of each individual conditionally on working. We then converted the incomes in multiples of the legal minimum wage, the unit we use in our model. The retained values are: 1.5 for individual with less than primary education, 2.1 for primary, 2.4 for lower secondary, 2.8 for upper secondary and 4.8 for tertiary education. Unfortunately the ENOE does not allow us to distinguish graduate from public and private schools. We therefore added 0.1 for none, primary and secondary and 0.2 for upper secondary and tertiary education to capture the private school premium.

Appendix C

Overview of parameters

The following table provides an overview of the different parameters of the model. The first column indicates the symbol we use for the parameter in this article, while the second column displays the abbreviation used in the Java code (computer program). The third column provides a short description and the last columns displays the value used in the basline model. Values with a $*$ are those values we changed in the sensitivity analysis.

Table C.1: Description of parameters

Symbol	**Parameter (Java)**	**Description**	**Value**
n/a	adjCostFiring	Adjustment cost of Firing a new worker (only formal firms pay this cost)	0.0*
n/a	adjCostHiring	Adjustment cost of Hiring a new worker (only formal firms pays this cost)	0.0*
γ_f	betaExpFormal	coefficient for formal experience	0.04*
γ_e	betaExpInformal	coefficient informal experience	0.02*
$\delta_{capital}$	capitalDestruction	possibility to destroy capital	0.8
$\delta_{business}$	capitalStartBusiness	Capital needed to start business	5.0
δ_d	depreciationRate	depreciation rate of capital and equity	0.05
θ_m	fineAmount	Fine for informality (multiple of total labour cost)	1.0
θ_p	fineProbability	firm's probability of be fined because it is informal	1%
n/a	init_N_families	Number of families at beginning	1000
n/a	ISR_fam_beta0	ISR(physical person): beta0	-0.1303969
n/a	ISR_fam_beta1	ISR(physical person): beta1	0.124559
n/a	ISR_fam_beta2	ISR(physical person): beta2	0.004959
π_{CIT}	isr_rate_firms	ISR paid by firms before a change in the policy	0.30
π_{CIT}	isr_rate_firmsPOST	Specifies the new rate of ISR after the new policy is implemented	variable
$\delta_{leverage}$	maxEquityLeverage	Max equity Leverage (for example, a value of "4" means four times equity in debt)	8.0
δ_{minAge}	minAgeParnterSearch	minimal age to start looking for a partner	15
n/a	newPolicy	Identifies the policy scheme after the threshold period. 1 refers to the status quo policy scheme, 2 to the policy scheme proposed in section 4.2	variable
δ	passingThreshold	Defined as threshold of health care divided by number of years	see A.3.3.3.5
p_{base}	PJO_base	base probability of fin a new job independent of other characteristics	0.5*
$p_{network}$	PJO_network	added probability of receiving a new job offer taking into consideration if the person has a lot of networks	0.1*
$p_{privateSchool}$	PJO_privateSchool	This added probability takes into account that a person with studies in a private school has greater chances to have job offers. In other words, this parameter is added probability of receiving a new job offer given that the person went to private school	0.1*
$p_{unemployment}$	PJO_unemployed	added probability of receive a job offer given that the person is unemployed	0.3*

–continued on next page–

Table C.1: Description of parameters (*continued*)

Symbol	**Parameter (Java)**	**Description**	**Value**
p_{mating}	prob_partnermatch	Mating: general probability of a match	0.5
n/a	prop_pension	propotion of the salary that will be given as pension given that person has IMSS	0.6
n/a	randomSeed	Default Random Seed, the set of random numbers used for simulate the results	variable
n/a	tickPolicyChange	Specifies when the policy is implemented in terms of numbers of periods. If this value is greater than 50, any policy will be implemented (because the maximum ticks in the simulation are 50)	25
τ_L	toleranceBelowAverage Income	the rate of tolerance of the family of earning an income below to their historic average income	0.8*
τ_{exp}	toleranceExpenditureLoss	Tolerance to expenditure loss (1.0 = no tolerance)	0.8*
η_{CSS}	treatmentCoefficientIMSS	effectiveness in health of getting IMSS treatment	0.9
η_{NCSS}	treatmentCoefficientSP	Treatment (health) coefficient Seguro Popular (informal)	0.45
n/a	tuition	Tuition/cost of public schools (in terms of minimum wage). The tuition levels for private schools are 1.6 for primary and lower secondary, 5.4 for upper secondary and 16.2 for tertiary education).	0.3
π_{VATg}	VATnormal	the initial normal VAT before a change in the policy	0.16
π_{VATg}	VATnormalPOST	VAT normal after a change in the policy	variable
π_{VATr}	VATreduced	The initial reduced VAT before a change in the policy	0.0
π_{VATr}	VATreducedPOST	The final reduced VAT after a change in the policy	variable

Appendix D

Sensitivity analyses

The aim of our sensitivity analysis is to study to what extent the results of our study are sensitive to some of the parameters used in the model. We are particularly interested in looking at the sensitivity to parameters for which we did not have empirical estimates. In this first version of the model we focused on the most critical parameters in our opinion. We define critical in the sense that we might expect the results to depend on these values. The baseline values are reported in appendix C. To perform the sensitivity analysis we ran the baseline model and the model with slightly different values. We report all results in Table D.1 and focus on the most relevant statistics.

Table D.1: Sensitivity analysis

Changes concepts/parameters	Income inequality	Educ. corr. father	Educ. corr mother	GDP	Formality	Avg. Educ
Adjustment costs for formal firms						
Baseline (Hiring=0, Firing =0)	0.359	0.329	0.309	80680.0	0.263	10.1
Hiring 0.5, Firing 1.0	0.387	0.322	0.299	85541.3	0.268	10.0
Hiring 0.5, Firing 1.5	0.390	0.325	0.298	87480.9	0.247	10.1
Hiring 1.0, Firing 2.0	0.395	0.328	0.302	88364.0	0.269	10.1
Hiring 2.0, Firing 3.0	0.407	0.322	0.304	95218.4	0.233	10.1
Effect of experience (formal and informal) of productivity						
Baseline (formal=0.4, informal=0.2)	0.359	0.329	0.309	80680.0	0.263	10.1
Formal =0.02, Informal = 0.02	0.350	0.319	0.301	80794.2	0.246	10.0
Formal =0.04, Informal = 0.03	0.358	0.327	0.309	86918.8	0.262	10.1
Formal =0.04, Informal = 0.04	0.363	0.329	0.307	85797.7	0.241	10.1
Formal =0.06, Informal = 0.02	0.359	0.325	0.304	80310.3	0.252	10.1
Probability of seeing job offers (base, unemployment effect, network effect, private school effect)						
Baseline (0.5,0.3,0.1,0.1)	0.359	0.329	0.309	80680.0	0.263	10.1
0.30,0.10,0.05,0.05	0.306	0.322	0.301	74569.6	0.365	10.1
0.40,0.20,0.15,0.15	0.318	0.326	0.310	75550.9	0.308	10.1
0.20,0.40,0.20,0.20	0.292	0.321	0.297	63448.2	0.374	10.1
Families tolerance to expenditure loss and income below average						
Baseline (income=0.8, salary= 0.8)	0.359	0.329	0.309	80680.0	0.263	10.1
Income = 0.6, salary=0.5	0.339	0.289	0.265	69196.1	0.261	9.8
Income = 0.7, salary= 0.7	0.351	0.317	0.293	75068.0	0.259	10.0
Income = 0.9, salary= 0.9	0.374	0.342	0.331	98601.1	0.263	10.2

Adjustment costs

In our baseline model we do not include adjustment costs for formal firms (hiring and firing adjustment costs). As we can see in Table D.1, most key statistics are not sensitive at all to this parameter. The only statistics that change are income inequality and to some extent GDP. This is an interesting results and opens new questions on why adjustment costs in the formal sector increase income inequality. In this version of the study we are not able to respond this question.

Effect of experience

The effect of experience on labour market productivity could also affect a wide range of statistics. We therefore ran the simulation for a series of values, but do not find any important change in the key statistics. Thus, this parameter set does not seem to be extremely relevant for the results.

Probability of seeing job offers

The likelihood of seeing job offer depends on many different elements, in particular on the labour market status. The results suggest that inequality, GDP and the proportion of formal firms are to some extent sensitive to these parameters. However, we have to highlight the rather extreme changes in this sensitivity analysis.

Tolerance to income and consumption loss

Finally, we look at the two *tolerance* parameters. On parameters captures how much individuals accept lower wages than what people with the same education level earn. The second tolerance parameter captures how much loss in consumption a family accepts from one period to the next. In the baseline model both values are set to 0.8 (80%). The education correlations are positively related to these two parameters, while the other statistics do not show much difference. GDP is also somewhat sensitive to these measures, but at this stage it remains unclear through which mechanisms the tolerance parameters affect GDP.

Appendix E

Agent-based modelling approach

A key element of this project is the use of agent-based modelling techniques rather than more traditional modelling techniques in economics. In this section we briefly introduce the ABM approach and highlight why it might be more appropriate and promising in achieving the goals of the project. More detailed introductions to agent-based models can be found in Gilbert (2008) and Miller and Page (2007). A discussion on the usefulness of ABM in development economics can be found in Chávez-Juárez (2016).

E.1 What are agent-based models?

Agent-based models are typically theoretical models that aim at reproducing real-world phenomena. Such models have been extensively used in various disciplines of natural science and are becoming more popular among social scientists. In economics, traditional equilibrium based models can be seen as top-down models, because the behaviour of typically representative individuals (micro level) is governed by the equilibrium condition (macro level). In contrast, agent-based models are bottom-up, where we model the behaviour at the micro level (processes, interactions, etc.) which then sum-up to produce some macro level outcomes that need not necessarily represent an equilibrium. Hamill and Gilbert (2015) define them in the following concise way:

> *"An agent-based model is a computer program that creates an artificial world of heterogeneous agents and enables investigation into how interactions between these agents, and between agents and other factors such as time and space, add up to form the patterns seen in the real world."* Hamill and Gilbert (2015).

Let us now have a closer at the notion of agents. Typically, we characterise an agent by characteristics (state variables) and behavioural rules (processes). Characteristics can be constant (e.g. gender, parental education) or variable (e.g. years of education, income) over time. At each point in time, an agent is characterised by the set of these state variables. The second major element of agents are behavioural rules. Behavioural rules describe what agents do in a given situation. For instance, a behavioural rule can govern the decisions to enrol or not at school. The behavioural rules are the equivalent to the resulting behaviour after the maximisation of a utility function in traditional models. These behavioural rules can be very simple (e.g. go to school whenever parents can afford it) or extremely complicated (e.g. the result of an intertemporal maximisation problem similar to traditional models).

When looking at a single agent, they are very similar to individuals in more traditional models. The important difference comes when we look at the whole population, because each agent can have different characteristics in each state variable and also in the behavioural rule. Hence, in agent-based models we do not have a representative agent or only heterogeneities in a few dimensions. An additional difference is that agent live in an environment, which is populated by other agents (of different types). Agents then interact with each other and the behaviour/decision of one agent will depend both on the state variables and the behaviour of other agents.

Another difference to traditional models is the large flexibility in the modelling approach due to the fact that no analytical solution must be computed. In traditional model it is many times intractable to include multiple optimisation behaviours and multiple heterogeneities. Given that in agent based model the behaviour is governed at the micro level and does not have to respect any equilibrium condition, it is virtually costless to add more decisions and dimensions5. Another advantage of this flexibility is that agent-based models can be built in a modular way, where in a first version some modules are oversimplified and then developed in subsequent versions of the model.

Finally, agent-based models do not only include heterogeneities in agents' characteristics and behaviour, but also in their outcomes. Hence, ABM are a natural way to study phenomena where the distribution of outcomes (e.g. education, earnings, etc.) are of primary importance.

E.2 Why ABM for this project?

For this project, the agent-based modelling approach seems to be the appropriate method for a number of reasons:

1. the number of processes to be included in the model is large and traditional models would most likely not be tractable or we would be forced to simplify the model beyond what could be justified.

2. the key outcome of interest is inequality and social mobility. As a consequence, model that heavily rely on representative agents or a limited number of types are ill suited and agent based models offer the possibility to study inequality within a generation but also from one generation to the next.

3. one of the goals of the project is to see how different concepts (e.g. social mobility, economic growth) evolve after a policy change. Agent-based models have an inherent time dimension and it is therefore easy to study both the short-run and the long run effects of a policy change.

4. Agent-based models allow us to get closer to reality by including both stylised facts and empirical evidence of the country of analysis. In our particular case, we can model many relevant processes by looking at the empirical evidence to ensure that these processes resemble what is observed in reality.

5. The possibility to build the model by modules and to oversimplify non-crucial elements in a first version is a huge advantage. We can therefore focus now on the core elements and include other phenomena in a passive way. Subsequently, we can then try to make the model more realistic by working on the oversimplified modules for a second and third version of the model.

E.3 Modelling process

The modelling process is somewhat different to the standard approach. We can simplify the process to the following steps:

1. Identify the different agent types in the model. In our case, we have multiple agent types such as individuals, families, schools and hospitals.

2. For each agent-type, we identify the processes that must be modelled. For instance, families must decide how to allocate their resources, whether they want to send the children to school and so forth.

3. For each of the processes we make a literature review and search for empirical evidence. We then analyse whether it is a crucial process for the study and we have to model it in detail, or if it is of secondary importance and we can use empirical evidence to make the process more mechanical.

4. For the most important processes we then start to model the behaviour of individuals. For instance, for the enrolment decision of children we identify the factors that might affect the decision and eventually model the actual decision.

5. Less important processes (or those that are not of primary interest for the study) which are still crucial for the model to work can be implemented in a simpler way. For instance, we know that fertility rates in Latin America are strongly influenced by the education level of the mother. This has direct consequences on social mobility. Nevertheless, the actual decision process of how many children a couple wants to have is not of primary interest and also beyond the scope of the study. In order to still have this phenomenon in the model, we can implement it in a passive way by looking at the empirical evidence and simple reproduce this evidence through a stochastic process that does not involve any active decision making of the agents.

6. Once each of the active decision making processes is roughly defined, we then look at how the different processes interact. For instance, in the labour market firms have a process to generate job offers and individuals have to take a decision on whether or not to accept a job offer. In this step we define how the two processes interact with each other and what kind of information is revealed to the other agents.

7. Once the full model is conceptualised in this way, we start with the programming of the model and to run preliminary analyses.

8. Once the model is fully operative, various runs with different settings and different stochastic random seeds are simulated and then analysed.

E.4 Technical implementation

We implement the model using the Repast Simphony packages in Java. Java has the advantage of cross-platform compatibility as it is executed on a virtual machine. All the simulations presented in this study were carried out on Microsoft Windows Workstations at the National Laboratory of Public Policy (LNPP).

Index