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# Essays in Development Economics

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# Declaration of Authorship

I, Manuel Alejandro Estefan Davila, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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# Abstract

This dissertation consists of three essays on three topics in Development Economics: gender equality, state capacity, and human capital. The first essay studies the effect of female labour force participation on gender violence. Using Mexican administrative records for a 10-year period, the study examines the impact of local variation in female employment resulting from changes in US demand for Mexican manufacturing in light industries and finds that increases in the population share of employed women lead to reductions in the male-female earnings gap while increasing the female-instigated divorce rate on the grounds of domestic violence, consistent with an "empowerment" effect. However, the study also finds an increase in homicide of married women, consistent with a "backlash" effect.

The second essay examines the effects of property tax rate changes on taxpayer behaviour in the context of weak enforcement capacity. Specifically, the study uses individual-level property tax records in Mexico City over five years and leverages variation from unexpected yearly tax rate hikes affecting only certain property value bands. The main finding of the study is that tax rate hikes lead to higher tax revenues but also provoke unambiguous reductions in tax compliance, worsening inequality in tax compliance.

The third essay proposes a structural approach to study the general equilibrium effects of public investments in schooling on the labour market. Schooling decisions are modelled as individual choices subsidised by the government in an overlapping-generations model. Social returns of human capital depend on the productivity of different schooling levels as production inputs. Estimation of the model using Mexican data on schooling and earnings reveals that public subsidies to college increase average wages and reduce earnings inequality. The reason is that individuals experience significant productivity gains after completing this schooling level, while college graduates are relatively scarce in the Mexican economy.

# Impact Statement

The findings of this dissertation provide insights into three important policy-relevant areas: gender equality, state capacity, and human capital.

**Gender Equality** The economic literature documents a long-lasting increase in female labour participation related to improvements in the educational attainment of women in advanced economies dating back to the late nineteenth century. Although somewhat more recent, this relationship is also present in developing economies. The consequences of this improvement in female access to the labour market on gender violence are of particular interest for the policy ambit. The central finding of the first chapter of this dissertation, that increases in the population share of employed women lead to reductions in the male-female earnings gap while increasing the female-instigated divorce rate on the grounds of domestic violence, is consistent with an "empowerment" effect, through which labour force participation allows women to escape violent situations at home. Simultaneously, the finding that female employment leads to an increase in homicide rates of married women emphasises the need for developing public policies to protect women against violence threats.

**Taxation and State Capacity** A transparent and well-functioning government that guarantees both the adequate functioning of markets and the provision of public goods is an indispensable condition for economic development. An especially important aspect of state capacity at the local level is the ability to raise revenues and spend them effectively since the quality of local public services depends on the available financial resources for the government. However, in most developing countries, the public sector fails to raise sufficient tax revenues in favour of their citizen due to constraints to enforcement and revenue administration. The second chapter of the dissertation studies the consequences of increasing tax rates instead of improving state capacity to increase tax revenues in contexts of weak enforcement. Relevant to policymakers is the finding that raising tax rates improves tax revenues but also leads to unambiguous and sharp reductions in tax compliance, worsening the tax burden on the group of dutiful taxpayers.

**Human Capital** A sharp rise in the relative earnings of college graduates in advanced economies is a well-documented phenomenon in economic literature. The so-called "skill-biased technological change", or the notion that technological progress and skills are complements, is among the underlying causes of this recent rise. This observed increase in the returns to skills raises important questions for policymakers. What is the optimal amount of investment in human capital for a society? Should governments invest more in education to guarantee that the labour force can keep up with the rate of technological progress? The third chapter of the dissertation finds that increasing public investment on college attendance would have a significant positive impact on average wages and reduce earnings inequality. The reason is that individuals experience higher productivity gains after completing this schooling level, while college graduates are relatively scarce in most developing economies.

# Table of Contents

# List of Figures

# List of Tables

# Chapter 1

# Employment Opportunities for Women and Gender-Based Violence: Evidence from Mexico

*"The secular growth in wages, which contributed significantly to the growth in the labour force participation of women, especially married women, probably also contributed significantly to the growth in divorce rates"* (Becker et al., 1977)

## 1.1 Introduction

Advanced economies have experienced a long-run increase in female labour force participation since the late nineteenth century (Goldin, 2006) and, similarly, labour force participation of women has grown faster than that of men over the last 50 years in developing countries (Duflo, 2012). Can these improvements in female labour market access empower women to leave toxic marriages? When women do not have attractive options outside marriage, the high bargaining power of males within marriage can lead husbands to sustain abusive behaviour towards their wives and their children, which has been shown to have negative consequences beyond productivity reductions, including chronic gynaecological disorders (Campbell, 2002), sexually transmitted diseases (Decker et al., 2008), and an increased likelihood of bearing babies with low birth weight (Valladares et al., 2002). If so, improving female labour market conditions would allow them to leave their husbands and stop this abusive behaviour.

A positive cross-country correlation between the ratio of female to male labour force participation and divorce rates, shown in Figure 1.1, provides support for this claim. Nonetheless, interpreting this relationship as causal is contentious because women in markets where intra-domestic violence is high, in principle, should have a powerful incentive to look for a source of employment to attain economic independence before filing for divorce, relative to markets in which domestic violence is less prevalent, and women do not have to look for a job as they have no pressing incentive for marital dissolution. Therefore, testing the hypothesis that the availability of labour market opportunities for women affects divorce decisions deserves more careful analysis.

This paper uses local variation in female employment from a Mexican export manufacturing program called *maquiladora* to identify the effect of female labour market access on divorce and gender-based violence at the market level. The program shelters the manufacturing operations of large US companies in light industries (i.e., food preparation, textiles and leather, electric appliances, and toys and plastic) and, during the period under study, represented on average 20% of all manufacturing jobs in Mexico, as well as 4.2% of the country's total employment.

The choice of export manufacturing of light industries in Mexico as a source of variation for causal inference is not fortuitous but obeys an exact logic, previously described by Ross (2008). First, historically, low-wage, export manufacturing of light industries has improved women labour market participation in developing countries, including Bangladesh, China, India, Morocco, South Korea, and Tunisia. Second, light industries employ mostly women, partly because making clothes and handicrafts are culturally-accepted women's work, and partly because these jobs do not require extraordinary physical strength. In fact, 80% of all the garment workers around the world are female (WorldBank, 2017). Third, export plants are even more likely to employ women because they are usually larger, have more employees and, for cultural or legal reasons, they do not discriminate on the basis of gender.

The paper uses individual-level administrative records on all (1) *maquiladora* plants, (2) major local labour markets, (3) divorces, (4) crime prosecutions, and (5) forensic reports in Mexico between 1997 and 2006, to construct quarterly outcomes at the commuting zone level. With this data, the essay estimates the effect of the local population share of *maquiladora* employment on local labour market outcomes, divorce rates, and several gender violence markers within marriage.

A simple comparison of the commuting zones where the *maquiladora* program operates and the rest of the commuting zones in the country, depicted in Figure 1.2, shows that both the population share of employed women and the divorce rate substantially increase after the signing of NAFTA, and fall with the entry of China to the WTO, in *maquiladora* commuting zones. These patterns in the data suggest that changes in US demand for Mexican manufacturing underlie the observed growth in female manufacturing employment and divorce rates in Mexico, highlighting the need for an empirical strategy that leverages precisely that source of variation to obtain causal estimates.

In particular, to obtain causal estimates, this study uses a shift-share type instrument for the local maquiladora employment share, which interacts two sources of variation: cross-sectional variation in local industry exposure to the program at baseline, and time-series variation in industry-wide changes in maquiladora employment. Using a shift-share type instrument is a particularly compelling strategy in this context due to three reasons. First, industry-wide changes in *maquiladora* employment reflect nation-wide shifts in US demand for Mexican manufacturing. As shown by Figure 1.3, the time series of *maquiladora* jobs at the national level closely follows the American demand for imports. Second, local participation in the program is plausibly random after controlling for distance to the US border, as revealed by Table 1.12. Finally, time series variation is differential across light and heavy industries, enabling the study of gender-specific shocks to labour demand. As depicted in Figure 1.4, the growth rate of employment fell for light industries but not for heavy industries after the entry of China to the WTO in 2001.

The central finding resulting from applying the shift-share instrumental strategy, concerning the effects of the program on local labour markets, is that *maquiladora* employment expansions improve the labour market conditions for men, but even more so for women. A percentage point increase in the *maquiladora* employment share improves average male earnings by 1.3 percent relative to baseline, while having no effects on the employment shares of men by sector. In contrast, a percentage point increase in *maquiladora* employment improves the population share of women employed in manufacturing by 7.4 percent relative to baseline, reflecting a drop in the inactivity share of 6.8 percent, while also improving average female earnings by 1.8 percent and reducing the average within-household male-female earnings gap by 1.7 percent.

Concerning the effects on divorce, a back-of-the-envelope calculation is that the program causes 0.16 new divorces per each 1,000 new female *maquiladora* employees. Additionally, the paper leverages a set of observables in the divorce administrative data to calculate the importance of different mechanisms in explaining this finding. First, the study verifies that relative improvements in female labour market conditions indeed increase only the number of female filings and not the number of mutual consent or male filings. Second, the paper shows that the increase in divorce rates corresponds to a hike in the number of filings on the grounds of domestic violence. This result implies that women who are filing for divorce indeed derive low benefits from marriage. Finally, the paper establishes that *maquiladora* employment breaks up marriages in which the wife works and has one or more children.

A question of interest is whether the increase in female-instigated divorces on the grounds of domestic violence reflects a rise in male aggression as a consequence of female employment, in which case violence could be interpreted as an instrument of control applied to women to prevent them from leaving marriage or improving their bargaining power within the household. This possibility has been previously studied in the literature. Using the responses of women to a survey in Bangladesh, Heath (2014) finds a correlation between female work and domestic violence and suggests that women with low bargaining power face increased risk of domestic violence upon entering the labour force as their husbands seek to counteract their improved bargaining position. This essay tests for a "backlash" effect by gathering administrative records on all domestic violence offences prosecuted in Mexico between 1997 and 2006 to construct local criminal rates. Results from this exercise indicate that *maquiladora* employment does not have an effect on the domestic violence rate for any demographic group of husbands. Despite finding no significant effects on domestic violence, the paper reports an alarming increase in the homicide rate of married women, constructed using forensic files, of 0.23 murders per 1,000 new female employees. A particular interpretation of this finding is that the threat of intra-domestic violence as an instrument of control is realised by some husbands.

All of the above results are robust to the usual set of robustness checks, such as controlling for time-varying local characteristics, including linear- and quadratic-specific trends, controlling for interactions of covariates at baseline with time trends, specifying placebo treatment dates and groups, and removing outliers and groups of cities from the analysis. Similarly, the instrument features a strongly significant partial correlation with the outcomes in the first stage and the reduced form. The results also pass the recent wave of robustness checks by Adão et al. (2018), Borusyak et al. (2018), Goldsmith-Pinkham et al. (2018), and Jaeger et al. (2018).

The contribution of this paper to the academic literature is threefold. First, this paper contributes to the literature on female empowerment and economic development (see Duflo, 2012) by filling the existing gap in the study of the relationship between female labour market conditions and divorce decisions in developing countries, where women are usually poorly protected by the law. Second, this paper contributes to the literature on the theoretical and empirical determinants of divorce decisions (see Browning et al., 2014 for a textbook treatment of the subject). At the heart of this vast area of study, pioneered by Becker et al. (1977), is the prediction that the probability of divorce falls with household income. So far, the majority of the existing empirical studies have found supporting evidence for this prediction (see Boheim and Ermisch, 2001; Charles and Stephens, 2004, and Hoffman and Duncan, 1995). In this paper, I provide novel evidence of an asymmetry in the effect of income on divorce decisions. Namely, increases in female income allow for divorce in situations where women suffer from Intimate Partner Violence. These findings relate to the results for advanced economies of Anderberg, Mantovan and Sauer (2018), Battu, Brown and Costa-Gomes (2013), Bertrand, Kamenica and Pan (2015), Folke and Rickne (2016), and Weiss and Willis (1997). Third, the paper studies the causal effects of substantial improvements to the potential income of women with low educational attainment on domestic violence in developing countries. Most of the previous studies either study advanced economies (see Aizer, 2010), or explore the effects of relatively small increases in income resulting from the expansion of cash transfers programs, including Angelucci (2008), Bobonis, González-Brenes and Castro (2013), Haushofer, Ringdal, Shapiro and Wang (2019), Hidrobo, Peterman and Heise (2016), and Hidrobo and Fernald (2013).

The remaining sections of the paper are structured as follows. Section 2 provides a conceptual framework. Section 3 presents the data used in the analysis. The institutional context and details about the maquiladora program are presented in section 4. Section 5 summarizes the IV empirical strategy that guides the empirical analysis. Section 6 presents the main findings of the study. The results from a battery of robustness checks are presented in section 7. Finally, conclusions and closing remarks are presented in section 8.

## 1.2 Conceptual framework

This section provides a theoretical model aimed at illustrating how improvements to the income of the wife can incentivise her to file for divorce, instead of lowering the divorce probability. The divorce decision is modelled in a two-period framework. In the first period, the female marries. In the second period, she learns about the quality of her husband and decides whether to remain married or file for divorce. The model focuses on the decisions made in the second period of the model and take the outcome of marriage markets as given. The following sub-sections detail the utility maximisation problem of the wife deciding whether to remain married or file for divorce, as well as insightful comparative statics.

#### Utility maximization if the wife remains married

Let $y_h$ denote the income of the husband, and let $y_w$ denote the income of the wife. Then, the total income of the couple is given by $Y_C = y_h + y_w$. Let $V^m : \mathbb{R}^+ \to \mathbb{R}$ denote the concave and continuously differentiable indirect utility function for the wife and her children from consumption of within marriage. Assume that the wife and her children have access to a share $\rho \in [0,1]$ of household income, determined via intra-household bargaining. Additionally, assume that they are subject to an equilibrium amount $v^m$ of violence within marriage, rendering a disutility of $f(v^m)$, where $f : \mathbb{R}^+ \to \mathbb{R}$ is a convex and continuously differentiable function. Finally, assume that marriage generates a non-pecuniary benefit $\theta \sim N(0,1)$, which is additively separable from consumption. Then, the indirect utility function of the wife if she remains married is given by $V^m(\rho(Y_C)) - f(v^m) + \theta_w$.

#### Utility maximization if the wife files for divorce

Let $V^d : \mathbb{R}^+ \to \mathbb{R}$ denote the concave and continuously differentiable indirect utility function for the ex-wife and her children from consumption after divorce. Assume that the non-pecuniary benefits of marriage become zero after divorce and that the wife pays a psychological cost $C$ of separation. Moreover, assume that, after filing for divorce but before consummating the separation, the wife and her children are subject to an amount $v^d$ of violence from the husband, rendering a disutility of $f(v^d)$. Finally, suppose the judge orders the ex-husband to share a fraction $\gamma$ of his income with his ex-wife. Then, the indirect utility function of the ex-wife is given by $V^d(y_w + \gamma y_h) - f(v^d) - C$.

#### The divorce decision and comparative statics

A necessary and sufficient condition for divorce is given by $V^m - f(v^m) + \theta_w \leq V^d - f(v^d) - C$, and the probability of female instigation for divorce before the realisation of the non-pecuniary gain from marriage is given by $\Pr[\theta_w \leq (V^d - f(v^d) - C) - (V^m - f(v^m))]$. Therefore, the effect of an increase in female income on the divorce probability is given by:

$$\frac{\partial \Pr[\theta \leq (V^d - f(v^d) - C) - (V^m - f(v^m))]}{\partial y_w} = \phi[(V^d - f(v^d) - C) - (V^m - f(v^m))] \cdot \left[ \left( \frac{\partial V^d}{\partial y_w} - \frac{df}{dv^d}\frac{\partial v^d}{\partial y_w} \right) - \left( \frac{\partial V^m}{\partial y_w}\left(\rho + \frac{\partial \rho}{\partial y_w} Y_C\right) - \frac{df}{dv^m}\frac{\partial v^m}{\partial y_w} \right) \right].$$

Hence, an increase increase in $y_w$ will raise the probability of female instigation for divorce if and only if the following inequality holds:

$$\frac{\partial V^d}{\partial y_w} - \frac{\partial V^w}{\partial y_w}\left(\rho + \frac{\partial \rho}{\partial y_w} Y_C\right) > \frac{df}{dv^d}\frac{\partial v^d}{\partial y_w} - \frac{df}{dv^m}\frac{\partial v^m}{\partial y_w}.$$

Above, the term in the left-hand side represents the utility gain from consumption resulting from filing for divorce, while the term in the right-hand side represents the utility loss from the increase in violence resulting from separation. The probability of divorce increases with the income of the wife if and only if the utility gain from consumption resulting from separation surpasses the utility loss from the increase in intimate partner violence provoked by the divorce decision.

The above inequality yields other valuable insights concerning the theoretical mechanisms motivating divorce decisions. First, divorce should be more likely when a substantial utility gain from consumption occurs with the separation decision. For example, if the arrival of a high-paying job raises the income of the wife above the subsistence level in the event of a divorce, the probability that she files for divorce increases unless her income raise also provokes an infinite amount of violence from her husband (i.e., the husband murders her).

Second, an increase in her income is likely to deter her from filing for divorce if that induces an improvement in bargaining power within marriage (i.e., $\frac{\partial \rho}{\partial y_w} > 0$). Indeed, Majlesi (2016) eloquently proves that the bargaining power of women within matrimony increases with female earnings, using precisely Mexican data.

Third, improvements in the income of the wife are likely to incentivize divorce if intra-domestic violence is "instrumental" in nature, or is applied as an instrument of control by the husband to steer part of the income of the wife towards his personal consumption (i.e., $\frac{\partial v^m}{\partial y_w} > 0$). In contrast, improvements in the income of the wife should reduce the probability of divorce if violence is "expressive", or is applied by the husband as an expression of frustration originated by low household income (i.e., $\frac{\partial v^m}{\partial y_w} < 0$).

Fourth, an income raise should positively affect the divorce probability if it negatively affects the amount of violence exerted by the husband after the wife decides to separate (i.e., $\frac{\partial v^d}{\partial y_w} < 0$). This would occur, for example, if the husband fears the legal consequences of violence when his wife has a high income that enables her to hire legal protection. On the other hand, an increase in income is likely to disincentivize divorce decisions if it positively affects the amount of violence exerted by the husband after the wife decides to separate (i.e., $\frac{\partial v^d}{\partial y_w} > 0$). For example, this would occur if the husband envies the improved labour market situation of his separating wife.

Fifth, a higher degree of altruism towards children exacerbates each of the mechanisms pertaining violence. For example, assume that the degree of altruism of the mother is governed by the parameter $\delta$, such that $f(v) = f_w(v) + \delta f_k(v)$, where $f_w$ is the disutility from violence for the wife and $f_k$ is the disutility for the children. Then, a higher value of $\delta$ will lead her to weight more seriously both intra-domestic violence and intimate-partner threats when making her decision. On the other hand, a higher degree of altruism is likely to moderate the utility gains from divorce if her income is insufficient to guarantee a subsistence consumption level for the children once the separation is consummated.

In summary, a higher income for the wife is likely to lead to an increase in the probability that she instigates for divorce if (1) her income raise would guarantee her consumption and that of the children to be above the subsistence level if she decides to separate from her husband, (2) her bargaining power within marriage does not substantially increase with her income, (3) the amount of violence exerted on her and the children if she decides to separate does not increase with her income, and (4) the amount of intra-domestic violence exerted on the wife and the children does not fall within marriage when her income increases. The following sections study the extent to which these theoretical channels are measurable in the data.

## 1.3 Data

To analyse the effect of improvements in female labour market conditions on divorce decisions and gender violence, this paper uses administrative records of all *maquiladora* plants in the country between 1997 and 2006, as well as administrative records of all divorces, domestic violence offences, and forensic reports in Mexico in the same period. Since the paper aims to estimate market-level effects, the paper aggregates individual-level data at the commuting zone level with a quarterly frequency and then links the resulting dataset to high-quality data from the labour force survey for the 45 urban commuting zones in the country.

### 1.3.1 Divorce data

The data used in this study consists of the universe of individual records of divorces in Mexico between 1997 and 2006. For each divorce, data includes the dates of matrimony, the filing of the divorce suit, and dissolution or consummation of the separation. Furthermore, administrative records provide the gender of the divorce instigator, the cause for the divorce, the number of children in the marriage, the gender of the custodian of the children designated by the judge, whether the judge mandated alimony and child support, and the gender of the alimony payee. Additionally, for each of the parties in each divorce, data includes age, place of residence, schooling, and information on occupation and labour market participation.

### 1.3.2 Maquiladora data

The paper uses plant-level administrative records from the *maquiladora* export industry between 1997 and 2006. Although the program started operating in 1965, the first year with complete records at the plant level is 1997. Plant-level data is extremely rich and includes monthly data on the number of employees, hours worked, wages, and benefits by gender. Moreover, the data details the economic activity of each manufacturing plant, as well as the nominal value of imported inputs, operating expenses and costs, output, and profits. The data is collected by the national institute of statistics of Mexico through a monthly census to all registered *maquiladora* plants in the country.

### 1.3.3 Socio-demographic data

Aggregate socio-demographic data at the commuting zone level comes from the quarterly labour force survey levied between 1997 and 2006, which is representative for each of the 45 largest commuting zones in the country. The raw data includes age, educational attainment, monthly earnings, occupation, and hours worked for all surveyed individuals. The paper uses this data to construct: average within-household earnings and hours worked by gender, as well as population counts and shares of mutually exclusive categories of labour market participation (i.e., manufacturing, non-manufacturing, and unemployed/not in labour force).

### 1.3.4 Crime data

This paper conducts additional analysis using administrative records of all prosecuted offences in the country on the grounds of domestic violence between 1997 and 2006. For each offence, data includes the date and place of occurrence of the event, whether the offence was consummated, the state of drunkenness of the offender, the date of prosecution, and the judge sentence, including prison time and fines. Finally, demographic characteristics of every offender are also recorded, including recidivism status, place of birth, gender, age, education, and occupation.

### 1.3.5 Forensic reports

To measure the realization of intimate partner threats, this paper uses individual-level administrative data of all deaths in Mexico for the period under study. This data is recorded by each civil registry and each criminal forensic investigator in the country. For each deceased individual, data includes the date and place of occurrence, the cause of death, and a set of socio-demographic characteristics of the deceased, including gender, age, educational attainment, occupation, and marital status. These individual-level characteristics inform the construction of homicide rates for married women.

### 1.3.6 Summary statistics

For the main analysis, this study constructs a quarterly dataset that includes data on all 45 commuting zones in the country, linking variables from the abovementioned sources. Specifically, at the commuting-zone level, it constructs intra-domestic violence rates, as well as divorce rates, homicide rates of women, average within-household earnings gaps, and the number of *maquiladora* plants and employees on a quarterly basis. Table 1.1 presents the means and standard deviations for the primary variables under consideration, along with the corresponding statistics for other relevant indicators, such as population counts.

## 1.4 Institutional context

This section describes in detail three crucial aspects of *maquiladora* program that make the use of a shift-share instrument a especially compelling empirical strategy to identify the effect of female labour force participation on divorce rates and intimate partner violence. First, industry-wide variation in *maquiladora* employment is a consequence of changes in US demand for imports, as revealed by a brief history of the program. Second, distance to the US border and access to the roads that lead to the US freeway system are the key determinants of local exposure to the program. Third, relative to the national industry, *maquiladora* plants offer disproportionately advantageous labour market conditions for women.

### 1.4.1 A brief history of the maquiladora program

The *maquiladora* program was created in 1965 to attract the manufacturing operations of foreign companies, with the aim of strengthening trade balance, boosting employment, and transferring technology from abroad. To this end, the program offers fiscal exemptions, labour costs reductions, and a 6-day work week to large foreign companies seeking to base their manufacturing operations in Mexico. The chief requisite for participation for foreign companies is to voluntarily enrol in the program by hiring a Mexican manufacturing contractor or a corporate shelter service that looks for appropriately-sized buildings to establish manufacturing operations. Participating US companies must temporarily import their inputs and export back their output to the US, guaranteeing that the operation of all *maquiladora* plants improves the balance of trade by exporting the value added by labour to the product.

Although the *maquiladora* program dates back to 1965, the signing of the North American Free Trade Agreement (NAFTA) on December 17, 1992 and its entry into force on January 1st, 1994 gave notoriety to the program as a crucial source of employment in Mexico. Figure 1.5 shows that the number of new jobs created by the program between 1995 and 2000 is greater than the sum of the number of jobs created in all previous periods combined, most likely due to an increased demand for Mexican manufacturing in the US, resulting from the removal of local content laws and local production requirements as part of the agreement.

In contrast, the entry of China to the WTO had negative consequences for *maquiladora* employment. As shown by the same figure, around 125 thousand jobs were destroyed between 2000 and 2005. In particular, *maquiladora* employment suffered a substantial setback on the 19th of September of 2000, the date in which the US Senate voted in favour of granting Permanent Normal Trading Rights (PNTR) to China, and a steep initial employment loss of 244,000 jobs was observed during the two years after that date. Since *maquiladora* jobs represented on average 4.2% of the country's total jobs between 1995 and 2006[1], the initial loss entailed a reduction of approximately 1% of the country's total employment.

### 1.4.2 The determinants of local exposure to the program

Supply factors largely determine plant openings and closures. According to documentary evidence from the main corporate shelter services in Mexico (not shown), supply factors determining the location decisions of foreign companies include the availability of amenities such as access to roads, proximity to the US border, local infrastructure, availability of buildings that meet the volumes and specifications required to assemble the products of a variety of companies, and commuting zone safety.

The importance of both proximity to the US border and access to roads with two or more lanes becomes evident when examining the geographical location patterns of *maquiladora* plants. Figure 1.8 presents a map of Mexico that depicts the location of all highways of more than two lanes with blue lines and the location of all commuting zones exposed to the *maquiladora* program between 1990 and 2006 with green stars. Most *maquiladora* municipalities are located near the US border or in commuting zones with direct access to the US via the freeway system.

The implications of this empirical regularity are twofold. First, *maquiladora* industry is relatively weak near the capital of the country, precisely where the national industry is strongest, implying that the coefficient from an OLS regression of the population share of manufacturing employment on the *maquiladora* employment share is likely to be biased towards zero. Second, local exposure to the program is relatively invariant since program participation is largely determined by proximity to the US border. This second implication makes the use of a shift-share instrument a particularly compelling empirical strategy, as shifts in US demand for Mexican manufacturing at the industry-level, conditional on local exposure, are the chief source of variation in *maquiladora* employment used by this instrument.

### 1.4.3 Favourable labour market conditions for women

*Maquiladora* plants are in general larger, employ more women, and pay higher wages than all other manufacturing firms. Table 1.2 compares the average characteristics of the universe of *maquiladora* plants to all other manufacturing firms in the country in 2004. While each *maquiladora* plant employs 381 individuals on average, all other manufacturing firms employ only 13 individuals. Moreover, the employment share of women is on average 49 percent in *maquiladora* plants, whereas this share is only 35 percent across all other firms. Finally, the average hourly wage in 2017 US dollars for workers in the assembly line is 4.26 in *maquiladora* plants, as compared to a far lower hourly wage of only 2.69 in 2017 USD for workers in all other manufacturing firms.

Beyond employing more women than the national industry, the *maquiladora* program offers fairer labour market conditions, as revealed by male-female earnings inequality. Figure 1.6 shows that the earnings gap is roughly three times as large in the national industry as in the *maquiladora* program. For instance, while the earnings gap across all *maquiladora* plants was 13.5 percent in 2001, the earnings gap in the national industry was at 43.4 percent in the same year.

[1] This estimate was elaborated with micro-data from the national labour force survey and the administrative records of the universe of *maquiladora* employment.

Importantly, the fraction of employment in female-intensive plants specialized in manufacturing textiles and electrical materials fell after the entry of China to the WTO in 2001, in favour of the fraction of male-intensive plants specialized in manufacturing transports and electronic items, providing a valuable source of differential variation in employment across industries. As depicted in Figure 1.7, plants in the electrical materials and textiles industries reduced their participation in total *maquiladora* employment from 48 percent in 2001 to only 36 percent in 5 years. In contrast, the participation of plants manufacturing transports and electronic products increased from 24 percent in 2001 to 33 percent in 2006. Employment in plants manufacturing food, shoes, furniture, chemical products, heavy machinery, toys, and other products also expanded during the same period.

## 1.5 Empirical strategy

This section begins by presenting a potential outcome framework, which emphasizes the existence of industry-specific effects of *maquiladora* employment, since some industries use female hours as a productive input more intensively than others. Next, the paper discusses the potential pitfalls of OLS estimation and proposes an IV shift-share strategy to recover the average effect of the program across all industries, along with the corresponding identifying assumption. Finally, the paper describes the construction of industry-specific estimates used in subsequent sections to study the effects of gender-specific shocks to employment. In what follows, argumentation is made in the absence of covariates, but all identification arguments in the case with covariates follow through directly from the Frisch-Waugh-Lovell theorem.

### 1.5.1 Potential outcome framework

Let $S^k_{z,t} = \frac{\text{Women in maquiladora jobs}^k_{z,t}}{\text{Population}_{z,t}}$ denote the population share of women employed by the *maquiladora* program in industry $k \in \{1,2,...,K\}$, and let $Y_{z,t}(S^1_{z,t},...,S^K_{z,t})$ denote the potential outcome of interest in commuting zone $z$ and quarter $t$ that would occur under exogenously set shares $\{S^k_{z,t}\}^K_{k=1}$. Then, the quarterly change in the potential outcome is given by:

$$\Delta Y_{z,t}(\Delta S^1_{z,t},...,\Delta S^K_{z,t}) = \Delta Y_{z,t}(\mathbf{0}) + \sum_k \Delta S^k_{z,t}\beta_k, \tag{1.1}$$

where the industry-specific effects of *maquiladora* employment are given by $\{\beta_k\}^K_{k=1}$. Different industries have distinct effects over the outcome of interest because some industries use female hours as a production input more intensively than others.

### 1.5.2 Average effect of the program

Instead of estimating the effects of the *maquiladora* program industry by industry, for the sake of parsimony, this paper estimates the parameter $\beta$ from the following regression:

$$\Delta Y_{z,t} = \Delta S_{z,t}\beta + \Delta\varepsilon_{z,t}, \tag{1.2}$$

where $Y_{z,t}$ denotes the observed outcome of interest, $S_{z,t} = \sum^K_{k=1} S^k_{z,t}$ denotes the total population share of women employed by the *maquiladora* program, and $\varepsilon_{z,t}$ is a zone-quarter-specific error term.

#### OLS estimation

This paper studies the asymptotics of the OLS estimator for the case in which the number of industries is small and therefore is taken as non-random, but the number of time periods is going to infinity, $T \to \infty$, and the number of commuting zones grows to infinity with time, or $Z \to \infty$ as $T \to \infty$. The conditions guaranteeing consistency and asymptotic normality of the OLS estimator are described in Proposition 1.

**Proposition 1** *Suppose that (1)* $E[\Delta Y_{z,t}(0)\Delta S_{z,t}] = 0$ *and* $E[\Delta\varepsilon_{z,t}|\Delta S_{z,t}] = 0$*; (2) the process* $\Delta S_{z,t}\Delta\varepsilon_{z,t}$ *is weakly stationary and has absolutely summable auto-covariances; (3) errors are uncorrelated over* $z$*; (4)* $E[(\Delta S^k_{z,t})^2] < \infty$*, and (4) shocks to maquiladora employment are uncorrelated over* $k$*. Then:*

1. $\hat{\beta} \xrightarrow{p} \beta$ *and* $\beta = \frac{\sum_{k=1}^{K} E[(\Delta S^k_{z,t})^2]\beta_k}{\sum_{k=1}^{K} E[(\Delta S^k_{z,t})^2]}$,

2. $\sqrt{ZT}(\hat{\beta} - \beta) \xrightarrow{d} N(0, \frac{J}{(\sum_{k=1}^{K} E[(\Delta S^k_{z,t})^2])^2})$*, where J is the long-run variance of* $\Delta S_{z,t}\Delta\varepsilon_{z,t}$.

Proposition 1 asserts that the OLS estimate of $\beta$ converges in probability to a weighted average of industry-specific effects, giving greater weights to industries where the *maquiladora* employment share has a higher variance. However, for Proposition 1 to hold, there should not be any correlation between quarterly changes in time-varying unobservable correlates of the local outcome of interest and quarterly changes in the *maquiladora* employment share. In the case of divorce, for example, such correlation can arise if local criminal violence affects both domestic violence and *maquiladora* employment within a commuting zone. Next, an IV strategy is proposed to address potential violations of the assumptions underlying OLS consistency.

#### IV estimation

To break the potential link between unobserved trends in the local outcomes of interest and the *maquiladora* employment share, this paper uses variation in *maquiladora* employment within each commuting zone, generated by local exposure to the program interacted with industry-specific shocks. In particular, this paper uses $\Delta B_{z,t} = \sum_{k=1}^{K} \chi^k_z \Delta M^k_t$ as an instrumental variable, where $\Delta M^k_t$ denotes the quarterly job openings at the industry level and $\chi^k_z = \frac{M^k_{z,t_0}}{M^k_{t_0}}$ denotes local exposure to the *maquiladora* program at baseline in industry $k$. The exogeneity condition $E[\Delta B_{z,t}\Delta\varepsilon_{z,t}] = 0$ required for consistency of the IV estimate of $\beta$ is met under the following identifying assumptions:

$$E[\Delta Y_{z,t}(0)\Delta M^k_t|\chi^1_z, ...\chi^K_z] = 0 \text{ and } E[\Delta\varepsilon_{z,t}\Delta M^k_t|\chi^1_z, ...\chi^K_z] = 0 \; \forall k \in \{1,2,...,K\}. \quad (1.3)$$

Essentially, the above assumptions amount to asserting that quarterly employment growth rates at the industry level are uncorrelated with local unobservable correlates of the outcome of interest in location $z$, conditional on the local exposure shares. The underlying rationale for this assumption is that industry-specific variation is likely to arise as a consequence of generalised changes in US demand for Mexican manufacturing over time, not from changes in the unobserved correlates of the outcomes of interest at the local level. Next, the conditions under which the 2SLS estimate of the *maquiladora* employment effect, denoted by $\tilde{\beta}$, is consistent and asymptotically normal are summarized.

**Proposition 2** *Suppose (1)* $E[\Delta Y_{z,t}(0)\Delta M^k_t|\chi^1_z, ...\chi^K_z] = 0$ *and* $E[\Delta\varepsilon_{z,t}\Delta M^k_t|\chi^1_z, ...\chi^K_z] = 0 \; \forall k \in \{1,2,...,K\}$*; (2) the process* $\Delta\varepsilon_{z,t}\Delta M^k_t$ *is weakly stationary and has absolutely summable auto-covariances* $\forall k \in \{1,2,...,K\}$*; (3) regression errors are uncorrelated over* $z$*; (4)* $E[\Delta S_{z,t}\Delta B_{z,t}] < \infty$*, and (4) industry-level shocks to maquiladora employment are uncorrelated over* $k$*. Then:*

1. $\tilde{\beta} \xrightarrow{p} \beta$ *and* $\beta = \frac{\sum_{k=1}^{K} E[\Delta S^k_{z,t}\Delta B_{z,t}]\beta_k}{\sum_{k=1}^{K} E[\Delta S^k_{z,t}\Delta B_{z,t}]}$,

2. $\sqrt{ZT}(\tilde{\beta} - \beta) \xrightarrow{d} N(0, \frac{J}{(E[\Delta S_{z,t}\Delta B_{z,t}])^2})$*, where J is the long-run variance of* $\Delta B_{z,t}\Delta\varepsilon_{z,t}$.

Proposition 2 implies that the IV estimate converges in probability to a weighted average of industry-specific effects, with greater weight awarded to the industries for which the instrument better predicts quarterly changes in local *maquiladora* employment shares. Notice also that the implied weights from IV estimation differ from the OLS estimation weights.

Although the instrumental strategy alleviates most endogeneity concerns that are present in OLS estimation, the identifying assumption could also be violated. For example, if changes in criminal violence in Tijuana lead to shifts in the local divorce rate and also affect US demand for Mexican products at the industry level, the identifying assumption would be infringed. This is precisely why this paper uses the period pre-dating the recent war on drugs in Mexico for estimation.

### 1.5.3 Industry-specific estimates

A key advantage of using a shift-share strategy to estimate the effect of *maquiladora* employment is that the main 2SLS estimate is numerically equivalent to a weighted sum of industry-specific estimates. Specifically, one can show that the 2SLS estimate of the *maquiladora* employment effect can be written as follows:

$$\hat{\beta} = \frac{\sum_{z=1}^{Z}\sum_{t=1}^{T}\Delta B_{z,t}\Delta Y_{z,t}}{\sum_{z=1}^{Z}\sum_{t=1}^{T}\Delta B_{z,t}\Delta S_{z,t}} = \sum_{k=1}^{K}\hat{\omega}_k\hat{\delta}_k. \tag{1.4}$$

Above, $\hat{\omega}_k \equiv \frac{\sum_{z=1}^{Z}\sum_{t=1}^{T}\chi_z^k\Delta M_t^k\Delta S_{z,t}}{\sum_{k=1}^{K}\sum_{z=1}^{Z}\sum_{t=1}^{T}\chi_z^k\Delta M_t^k\Delta S_{z,t}}$ denotes the Rotemberg weight of industry $k$, which depends on the strength of the correlation between industry-specific shocks and local quarterly changes in the *maquiladora* employment share. On the other hand, $\hat{\delta}_k = \frac{\sum_{z=1}^{Z}\sum_{t=1}^{T}\chi_z^k\Delta M_t^k\Delta Y_{z,t}}{\sum_{z=1}^{Z}\sum_{t=1}^{T}\chi_z^k\Delta M_t^k\Delta S_{z,t}}$ is the 2SLS estimate resulting from regressing quarterly changes in the outcome of interest, $\Delta Y_{z,t}$, on the local changes in the *maquiladora* employment share, $\Delta S_{z,t}$, instrumented using nation-wide quarterly shocks to employment in industry $k$, $\Delta M_t^k$, and using the local exposure shares in the same industry, $\chi_z^k = \frac{M_{z,t_0}^k}{M_{t_0}^k}$, as regression weights. Proposition 3 provides conditions under which $\delta_k$ estimates are consistent and asymptotically normal.

**Proposition 3** *Suppose that the assumptions in Proposition 2 hold. Then:*

1. $\hat{\delta}_k \xrightarrow{p} \delta_k$ *and* $\delta_k = \frac{\sum_{j=1}^{K}E[\Delta M_t^k\Delta S_{z,t}^j]\beta_j}{\sum_{j=1}^{K}E[\Delta M_t^k\Delta S_{z,t}^j]}$,
2. $\sqrt{ZT}(\hat{\delta}_k - \delta_k) \xrightarrow{d} N(0, \frac{J}{(E[\Delta S_{z,t}\chi_z^k\Delta M_t^k])^2})$, *where $J$ is the long-run variance of* $\Delta M_t^k\Delta\varepsilon_{z,t}$.

Proposition 3 reveals that each $\delta_k$ is a different weighted average of the effects of interest, giving greater weights to the effects of industries for which local changes in the *maquiladora* share correlate more closely with employment shifts in industry $k$. Hence, these industry-specific estimates will be useful to analyse the effects of gender-specific shocks since, for example, shifts to employment in a female-intensive industry are likely to correlate with local shifts in the *maquiladora* employment share of other female-intensive industries.

## 1.6 Main results

This section presents the effect of female employment in the *maquiladora* program on local labour market outcomes, divorce rates, and intra-domestic violence in large urban commuting zones in Mexico between 1997 and 2006. The text begins by analysing the effect of *maquiladora* employment on female labour force participation. Next, the paper reports the impacts of *maquiladora* employment on the population shares of other employment sectors by gender to establish the presence of potential spillovers and examines the effects of the program on average within-household earnings inequality. Finally, the text turns to investigate the impact of *maquiladora* employment on divorce decisions and domestic violence.

### 1.6.1 Female labour force participation

Table 1.3 reports the effect of the population share of women employed by the *maquiladora* program on the overall female employment share. Column (1) of the table presents a strongly significant OLS estimate of 0.432 from the baseline specification with only commuting zone fixed effects and time dummies. This estimate implies that a percentage point increase in the female *maquiladora* share leads to an increase of 0.432 percentage points in the overall female employment share. The OLS estimate is likely to be negatively biased, since *maquiladora* plants tend to locate in commuting zones near the US border, where foreign companies tend to crowd out the national manufacturing industry, and they tend to absent where the national industry is strong.

Column (2) presents the estimates from the baseline specification of the IV model. The first stage instruments the population share of women employed by the *maquiladora* program with the shift-share instrument described in the previous section. The first stage coefficient on the shift-share instrument is about 0.13. It implies that an exogenous shock of 100,000 new *maquiladora* jobs leads to an increase in the *maquiladora* employment share of 13 percentage points on average. The first stage is strong, with an F-statistic of 23.2, which rules out usual concerns related to weak instrument bias.

Turning to the second stage, the baseline estimate of 0.959 is significant at the 1 percent level. It implies that a percentage point increase in the female *maquiladora* employment share leads to a significant increase in the overall female employment share of 0.959 percentage points. Hence, the OLS estimate underestimates the effect of *maquiladora* employment.

Moreover, since proximity to the US border is an essential determinant of *maquiladora* plant location, estimates in column (3) allow the variance of the error term in the above regression to be proportional to the distance of the commuting zone to the US border by weighting observations. Specifically, estimates in this column weight observations by the reciprocal of the square root of the commuting zone distance to the US border, assuming that the variance of the error term in the above regression is proportional to the distance of the commuting zone to the US border. Furthermore, estimates in this column control for a large vector of covariates, including a lag of female labour force participation, other lagged labour market indicators, and population composition at baseline. Both the first and second stage estimates remain remarkably similar in terms of significance and magnitude.

Columns (4) through (7) include control variables to test the extent to which the IV estimates of the effect of *maquiladora* employment on overall female employment are sensitive to modifications in the empirical specification. To address the possibility that a correlation between *maquiladora* employment and commuting-zone-specific trends in overall manufacturing drives the baseline estimates, columns (4) and (5) report the IV estimates after the inclusion of linear- and quadratic-specific trends in manufacturing. IV estimates are similar to the estimates that weight observations by the distance of the commuting zone to the US border. Finally, the table tests for the possibility that the effect is driven by correlations between *maquiladora* employment and trends in overall manufacturing that depend on the pre-NAFTA characteristics of the commuting zones. To address this possibility, columns (6) and (7) present the results from including interactions of baseline covariates with either a linear time trend or time dummies. IV estimates remain largely unchanged in both cases.

### 1.6.2 Spillovers to male employment and other sectors

Next, the paper moves on to examine the effects of exposure to the *maquiladora* program on population shares by employment category to account for the potential spillovers of the program. Population shares are constructed by sorting the working-age population (16-69 years old) in each commuting zone into three exhaustive and mutually exclusive employment categories: manufacturing employment in the assembly line, non-manufacturing employment, and unemployment/inactivity. The first three columns of Table 1.4 report the effect of female employment in the *maquiladora* program on the population share of each of these employment categories, and the sum of effects across categories adds to zero by construction. Estimates in the first row of the table indicate that a percentage point increase in the *maquiladora* employment share leads to a significant shift of the population away from unemployment by 0.759 percentage points into manufacturing and non-manufacturing employment by 0.164 and 0.593 percentage points, respectively.

The second and third rows of the table examine the effects of female *maquiladora* employment separately for men and women. A percentage point expansion in the population share of women employed by the *maquiladora* program does not lead to any statistically significant shift of men across employment categories. In contrast, a percentage point expansion of the *maquiladora* program results in a strongly significant reduction of the population share of inactive women by 0.96 percentage points, or 6.8 percent relative to baseline, as well as in an improvement in the share of women employed in the assembly line of 0.233 percentage points, or 7.4 percent relative to baseline. Additionally, the same expansion raises the share of women employed in the non-manufacturing sector by 0.732 percentage points, or 4.3 percent relative to baseline. Overall, the program reduces the gap between men and women in terms of labour force participation.

### 1.6.3 Average within-household earnings inequality

Column (4) of Table 1.4 reports the effect of *maquiladora* employment on average within-household monthly earnings by gender and on earnings inequality. Concerning average within-household earnings by gender, a percentage point expansion in the population share of women employed by the *maquiladora* program raises household earnings by 2.709 percent, reflecting an increase of 1.333 percent in male earnings and an improvement in female earnings of 1.786 percent relative to baseline. However, despite the fact that *maquiladora* employment improves both male and female earnings, the program is disproportionally beneficial to women, as reflected by an average reduction of 1.662 percent in the within-household male-female earnings gap.

### 1.6.4 Divorce

Table 1.5 presents the baseline IV estimates of the effect of *maquiladora* employment on local divorce rates, constructed as the number of divorces filed in the commuting zone within each quarter per 1,000 individuals. Column (1) of Panel I shows that a percentage point increase in the *maquiladora* employment share leads to a rise in the divorce rate of around 1.07 new filing per 1,000 individuals, although the effect is noisily estimated and is therefore non-significant. This estimate implies that the arrival of 1,000 new *maquiladora* jobs to a commuting zone leads to 1.07 new divorce filings.

The paper now turns to examine the effect of *maquiladora* employment on divorce rates by gender of the instigator. To this end, all divorce filings are sorted into the exhaustive and mutually exclusive categories of mutual consent, female-instigated, and male-instigated filings. By construction, the sum of effects across categories adds up to the overall impact of 1.07 new filing per 1,000 individuals. Panel I of the table shows that the lion's share of the increase in the overall divorce rate corresponds to a significant rise of 0.828 female-instigated divorce filings per 1,000 individuals. In contrast, the *maquiladora* employment share has no noticeable effect on either the male-instigated filings or the mutual consent divorce rate. These results yield critical theoretical insights. If the observed effect of exposure to the *maquiladora* program on the divorce rate were explained by an increase in the number of divorces filed by mutual consent of both spouses, bargaining within the couple would most likely underlie the divorce decision. However, since the effect is explained by an increase in the number of divorces instigated unilaterally, a one-sided gain in utility from the divorce decision is a more likely explanation for the observed rise in the divorce rate.

Next, the paper examines the grounds on which females file for divorce. Since a mutual consent divorce regime was in place in Mexico up until 2008, a spouse could only instigate for divorce unilaterally by providing proof of case that her partner had incurred in a sufficiently severe fault to his marriage obligations. Thus, the paper uses available data on separation causes to construct cause-specific divorce rates by sorting all divorces instigated by females into exhaustive and mutually exclusive categories. Panel II of the table indicates that a percentage point increase in the *maquiladora* employment share gives rise to a strongly significant rise of 0.158 female-instigated divorce filings on the grounds of domestic violence per each 1,000 new employees. Moreover, *maquiladora* employment also gives rise to 0.288 new female-instigated divorces on the grounds of insufficient monetary support of the husband. No significant effects of *maquiladora* employment on all other divorce grounds, including abandonment and adultery, are found.

Exposition continues by studying whether the group of women instigating for divorce is the same as the group of potential beneficiaries of the *maquiladora* program, composed mainly by employed women. In Panel III of the table, the effect of *maquiladora* employment on female-instigated divorce is decomposed by the employment status of the wife. Column (1) reveals that the program results in a strongly significant rise in the number of divorces instigated by employed women. In contrast, *maquiladora* employment has no significant effect on the number of divorces instigated by unemployed/inactive women, as shown by column (2) of the table.

The paper continues by studying whether the increase in the number of divorces instigated by females corresponds to the break-up of marriages with children or the separation of childless couples. To determine whether the effect of exposure to the *maquiladora* program on the female-instigated divorce rates corresponds to marriages with children or childless matrimonies, all female-instigated divorces are sorted into those in which the couple has children and those in which the couple is childless. Then, rates per 1,000 individuals are constructed for each of these outcomes. Columns (3) and (4) of Panel III of the table present the baseline IV estimates for each of these rates. A percentage point increase in the *maquiladora* employment share raises the divorce rate for couples with one or more children but has no significant effect on the female-instigated divorce rate for childless matrimonies.

### 1.6.5 Intra-domestic violence

A question of interest is whether the increase in female-instigated divorces on the grounds of domestic violence reflects a rise in male aggression as a consequence of female employment, in which case violence could be interpreted as an instrument of control applied to women to prevent them from leaving marriage or improving their bargaining power within the household. This possibility has been previously studied in the literature. Using the responses of women to a survey in Bangladesh, Heath (2014) finds a correlation between female work and domestic violence and suggests that women with low bargaining power face increased risk of domestic violence upon entering the labour force as their husbands seek to counteract their increased bargaining power.

The paper tests for this effect by gathering administrative records on all domestic violence offences prosecuted in Mexico between 1997 and 2006 to construct local criminal rates. Panel I of Table 1.6 presents the effects of *maquiladora* employment share on domestic violence offence rates by the employment sector of the offender and his state of drunkenness. Effects are non-significant for all groups under consideration, even for the group of husbands working in the non-manufacturing sector that commit acts of violence under the influence of alcohol.

Nevertheless, the absence of an effect on domestic violence prosecutions does not necessarily indicate the lack of a behavioural effect, as female employment opportunities might lead to the realisation of extreme forms of domestic violence. Panel II of the table shows the effect of a percentage point expansion of the *maquiladora* program on the homicide rate of women by marital status of the victim. These homicide rates are constructed by aggregating individual-level forensic reports and civil registry records. Column (3) shows a striking increase of 0.23 homicides of married women per each 1,000 new employees, while no significant effect is found for any other group of women under consideration. A particular interpretation of these findings is that some threats of violence are materialised. In other words, female employment not only allows women to escape situations of domestic violence, but also puts them at risk of suffering from extreme forms of Intimate Partner Violence in the absence of adequate legal protection.

## 1.7 Robustness checks

This section presents the results from a battery of robustness checks conducted around the baseline IV estimates of the effect of the *maquiladora* employment share on local labour market outcomes, divorce rates, and gender violence. First, the text tests whether slight modifications to the selected sample or the empirical specification drastically change the magnitude or significance of the critical estimates in the paper. Second, the paper conducts two placebo tests to address a couple of pressing concerns about estimation validity. Namely, the paper discusses the possibility that *maquiladora* plants decide to locate in commuting zones with a higher supply of non-college divorced women in an attempt to access cheaper labour, as well as the concern that an omitted variable might cause both *maquiladora* plant openings and changes in divorce rates at the commuting zone level. Third, the article tests whether the opening or closure of plants results in internal migration or changes in the log-population counts for an exhaustive set of demographic groups in the commuting zone. Finally, the paper conducts all novel robustness checks proposed recently by Adão, Kolesár and Morales (2018), Borusyak, Hull and Jaravel (2018), Goldsmith-Pinkham, Sorkin and Swift (2018), and Jaeger, Ruist and Stuhler (2018).

### 1.7.1 Sensitivity of the results to the choice of sample and specification

Table 1.7 reports the results from a series of tests showing that the selection of the sample does not drive the estimated effects on key outcomes in the paper. Column (1) of the table shows the baseline IV estimates of the impact of *maquiladora* employment on the female employment share, the female-instigated divorce rate, and the homicide rate of married women. Column (2) shows the estimated effects of removing outliers from the second stage of each regression. The results for the three variables remain highly significant, and the effect of the *maquiladora* employment share on log earnings of females increases in magnitude. In column (3), I present the effects after removing observations for which the value of the outcome of the second-stage regression is zero. The magnitude of the effects on the variables under consideration remains unchanged, but the impact on the female-instigated divorce rate is less precisely estimated. Column (4) shows the results when the 3 largest commuting zones are removed from the sample. For all three variables, both the significance and the magnitude of the estimates remain mostly unaltered.

Table 1.8 tests the sensitivity of the estimated effects to the inclusion of different groups of time-varying controls. Columns (1) and (2) present the baseline OLS and IV second-stage estimates for the same critical outcomes as in the previous table. Column (3) shows the second-stage IV estimates after weighting observations by the reciprocal of the commuting zone distance to the US border and controlling for a large vector of covariates. Columns (4) and (5) present the second-stage IV estimates after the addition of linear- and quadratic-specific trends in each outcome. Finally, columns (6) and (7) report the second-stage IV estimates after the inclusion of interactions of baseline covariates with either a linear trend or time dummies. For all variables under consideration, estimates after the addition of time-varying covariates are nearly identical to the baseline estimates.

### 1.7.2 Placebo tests of reduced-form effects

Table 1.9 reports the results from placebo tests used to address two remaining concerns around the validity of the IV estimates. The first concern is that *maquiladora* plants might locate in commuting zones where the supply of non-college divorced females is high in an attempt to access cheap labour. If this were indeed the case, shift-share shocks should correlate with chronologically-distant changes in divorce rates. To test for this possibility, 10-quarter lags of local female-instigated divorce rates are regressed on the current shift-share instrument, while controlling for commuting zone fixed effects and time dummies. Estimates in column (2) of the table present the results from this exercise. No statistically significant effects of current shift-share shocks on lagged values of the female-instigated divorce rate are found. In contrast, estimates in column (1) present positive and statistically significant reduced-form effects of shift-share shocks on contemporaneous quarterly changes in female-instigated divorce rates.

A second concern is that an omitted variable might cause both shift-share shocks and hikes in divorce rates. For example, increases in the US demand for Mexican *maquiladora* employment could correlate with increases in the demand for illegal immigrant workers in the US, in which case some of the wives left behind would file for divorce, mechanically giving rise to a rise in the divorce rate. The paper tests for this possibility by including shift-share shocks happening between $t$ and $t+1$ as an instrument in the reduced-form regression of the IV model, instead of the shift-share shocks happening between $t-1$ and $t$. If an omitted variable indeed caused shift-share shocks and divorce rates, one would observe a significant effect of future plant openings on current divorce rates even when events in the future have not yet changed the *maquiladora* employment share in the commuting zone. Columns (3) through (5) present the results of this exercise. Column (3) shows a positive and significant effect of the contemporaneous shift-share shocks on current divorce rates, whereas column (4) presents no statistically significant effects of future shift-share shocks. Column (5) shows the p-values of the t-tests used to examine these differences formally.

### 1.7.3 Effects on population size and migration

A potential concern when analysing the effects of *maquiladora* employment on local labour markets and divorce rates is that migration into the treated commuting zones could be mechanically driving the results. Consider for instance an inflow of married females that, seeking to attain economic independence, move into the treated commuting zone and only then file for divorce. In such a scenario, the divorce rate would mechanically increase as a consequence of *maquiladora* employment, even in the absence of behavioural responses of native females to treatment. To test for this possibility, the paper estimates a regression of the quarter-to-quarter change in the log population counts by demographic sub-group at the commuting zone level on the *maquiladora* employment share instrumented using the shift-share instrument. Results from this exercise are presented in Table 1.10. The paper finds no evidence, for any of the demographic groups under consideration, of a positive change in log-population counts at the commuting zone level arising from the arrival of *maquiladora* employment. These results are evidence against the premise that the effects reported in this study might be caused by internal migration or by a change in population counts instead of reflecting an actual behavioural response of the group of treated females. Furthermore, these results are consistent with the findings in a previous study by Atkin (2016), which reports no significant effects of manufacturing opportunities in Mexico on local population size.

### 1.7.4 Exogeneity of local exposure to industry-level shocks

Next, this study turns to interpreting the results described above under the umbrella of the recent paper by Goldsmith-Pinkham et al. (2018), which shows that shift-share instrumental strategies are numerically equivalent to using local exposure shares as instruments and industry-wide employment changes as regression weights. In turn, the authors of that paper propose a battery of tests to assess the plausibility of the orthogonality restrictions required for consistency of the IV estimate. Relevant for this study, they propose: (1) measuring the correlation between local exposure to the *maquiladora* program in each industry and the observable characteristics of the commuting zone at baseline; (2) conducting over-identification tests for a number of different IV estimators (i.e., 2SLS, MB2SLS, LIML, and HFUL); and (3) estimating the Rotemberg weights to measure the percentage bias that could arise through direct effects of exposure to the program in each industry. Below, the text presents the results from conducting these tests.

First, Table 1.12 presents the results from measuring, via OLS regression, the correlation between the local exposure to the *maquiladora* program in each industry and a vector of characteristics of the commuting zone at baseline. Once controlling for commuting-zone distance to the US border, this study finds no evidence of a systematic correlation between local exposure to the *maquiladora* program and local observable characteristics. Formal F-tests are unable to reject the null hypothesis of joint irrelevance of these variables in explaining local exposure to the program.

Second, Table 1.11 presents the effect of the *maquiladora* employment share on divorce rates, as measured by all the estimators proposed by Goldsmith-Pinkham et al. (2018). Column (1) presents the estimators without controlling for the baseline characteristics of the commuting zone. The effect of the *maquiladora* employment share on female-instigated divorce on grounds of domestic violence is strongly significant across all estimators and remains stable around the original shift-share estimate for all but the HFUL estimator, for which the estimated effect is more than five times the original shift-share estimate. Column (2) shows the estimates that result from including the observable characteristics of the commuting zone at baseline as controls, and Column (3) reports the p-value from a simple t-test of differences in the coefficients in columns (1) and (2). Inclusion of baseline characteristics of the commuting zone as controls does not substantively affect the results, as the tests for equality of coefficients across specifications do not reject the null hypothesis for any of the estimators under consideration. Finally, column (4) presents the J-score and the corresponding p-value of an over-identification test for the estimators that use industry exposure shares as instruments for *maquiladora* employment. In all cases, the J-scores are insufficiently high to reject the exogeneity restrictions required for identification.

Third, Figure 1.9 presents the industry-specific effects and Rotemberg weights, along with related summary measures. As shown in Panel (a), the shift-share estimate gives a high weight to the electrical industry, which has a positive and strongly significant effect on the female-instigated divorce rate, as depicted in Panel (b). This industry is also the one with the second highest share of female employment, only after textiles, and the industry with the highest *maquiladora* employment share, as shown by panels (c) and (d). On the other hand, panels (e) and (f) reveal no clear relationship between the Rotemberg weights and the variance of the initial exposure to the *maquiladora* program or the average quarterly employment growth. Hence, consistency of the shift-share estimate hinges on the orthogonality restriction for the electric industry.

### 1.7.5 Exogeneity of industry-level aggregate shocks

Instead of relying on the exogeneity of local exposure to industry-level shocks, in a recent article, Borusyak et al. (2018) derive necessary and sufficient conditions under which identification of causal effects in shift-share studies comes from exogenous industry-level shocks. They propose estimating the parameters of interest using industry-level regressions, which yield consistent estimates under the assumption that aggregate shocks are uncorrelated with a weighted average of the unobservable correlates of the regression outcome, with local exposure levels to industry-specific shocks acting as regression weights. They also suggest regressing the weighted average of the lagged residualized changes in the outcome of interest on the current industry-level shocks as a test for pre-trends. This section presents the results from estimating the effect of *maquiladora* employment via industry-level regressions, as well as the results from their suggested test for pre-trends.

For the case at hand, following Borusyak et al. (2018), one can show that the shift-share estimate of the *maquiladora* employment effect, resulting from estimating model (1.2) via 2SLS, is numerically equivalent to regressing the industry-specific weighted average of quarterly changes in the residualized outcome of interest, denoted by $\overline{\Delta y_{z,t}}^k = \frac{1}{Z}\sum_{z=1}^{Z}\chi_z^k \Delta y_{z,t}$, on the weighted average of quarterly changes in the residualized *maquiladora* employment shares, denoted by $\overline{\Delta S_{z,t}}^k = \frac{1}{Z}\sum_{z=1}^{Z}\chi_z^k \Delta S_{z,t}$, instrumented using the industry-level shocks to *maquiladora* employment, or:

$$\begin{aligned}\hat{\beta}^{2SLS}_{\text{Bartik}} &= \frac{\sum_{z=1}^{Z}\sum_{t=1}^{T} B_{z,t}\Delta y_{z,t}}{\sum_{z=1}^{Z}\sum_{t=1}^{T} B_{z,t}\Delta S_{z,t}} \\ &= \frac{\sum_{k=1}^{K}\sum_{t=1}^{T} \Delta M_t^k \overline{\Delta y_{z,t}}^k}{\sum_{k=1}^{K}\sum_{t=1}^{T} \Delta M_t^k \overline{\Delta S_{z,t}}^k}.\end{aligned} \tag{1.5}$$

Table 1.13 presents the results from estimating the effect of *maquiladora* employment on the female-instigated divorce rate on grounds of domestic violence using industry-level regressions as in (1.5). Column (1) presents the results from the baseline specification, in which both the divorce rate and the *maquiladora* employment share are first projected on commuting zone fixed effects and time dummies, and then the residualized values of these variables are used to construct industry-specific weighted averages used in an industry-level regression. Column (2) shows the resulting estimates after controlling for industry-specific characteristics, such as the the average monthly earnings of employees and the number of female workers as a share of total employment. Column (3) depicts the estimates from specifying an AR(1) for industry-specific employment changes and using the residuals from an AR(1) regression of industry-specific shocks as an instrument instead of the original shift-share. The effect of the *maquiladora* employment share is stable and significant across all specifications. Finally, column (4) presents the results from a pre-trends check, in which a five-quarter lag of the divorce rate is used as an outcome. This pre-trend check finds no effect of the current *maquiladora* employment share on the lagged value of the divorce rate, indicating that an omitted variable is not causing both variables to change.

### 1.7.6 Correlation in errors across regions with similar industry composition

In a recent article, Adão et al. (2018) show that spurious inference can arise from shift-share studies when unobserved shocks are correlated across regions with similar industry composition, even under the orthogonality restrictions required for consistency. They derive the asymptotic distribution of the shift-share estimator when the number of industries grows large and develop a standard error formula that accounts for correlation in model residuals across regions with similar industry composition[2].

Despite having only 12 industries in this study, this paper calculates their adjusted standard errors for the effect of the *maquiladora* employment share on the female-instigated divorce rate on the grounds of domestic violence. Results from this exercise are shown in Table 1.14. Column (1) presents the first stage coefficient along with different estimates of its standard deviation. Importantly, the standard deviation of the first-stage coefficient is larger when assuming clustered and heteroskedastic residuals than when using the AKM or AKM0 procedures, indicating that cross-regional residual correlation plays a less important role than within-region correlation in explaining the variance of the first-stage residuals. Similarly, the estimates of the standard deviation for the reduced form coefficient, presented for in Column (2), reveal that unobserved determinants of divorce are not severely correlated across commuting

[2] Throughout their analysis, Adão et al. (2018) make three identifying assumptions: (1) that the industry-specific shocks are as good as random conditional on exposure, (2) no single industry is too important, or $\frac{\max_s n_s}{N} \to 0$, which holds trivially in this case because $\sum_{z=1}^{Z} s_{z,t_0} = 1$ for all $k$ industries; and (3) that the number of sectors goes to infinity.

zones with similar industry composition, since the standard deviation resulting from applying the AKM or the AKM0 procedures is smaller than the standard deviation resulting from assuming clustered and heteroskedastic residuals. Finally, Column (3) shows that accounting for residual correlation across commuting zones with similar industry composition leads to a smaller standard deviation in the second stage than that resulting from assuming clustered and heteroskedastic residuals.

### 1.7.7 Dynamics: short vs. long run effects

Another potential concern surrounding the shift-share estimate is that spatial stability in exposure to the *maquiladora* program can lead to spurious inference if current realisations of the instrument correlate with ongoing behavioural responses to previous *maquiladora* employment shocks. In the case of divorce, a long-run improvement in marital quality stemming from the increase in female earnings may lead to a drop in female-instigated divorces in the long run, even when in the short run the improvement in female labour market participation leads to the separation of marriages suffering from domestic violence[3]. To address this possibility, the paper conducts the "multiple instrumentation" strategy suggested by Jaeger, Ruist and Stuhler (2018) in the context of the migration literature to determine whether current realizations of the instrument correlate with ongoing behavioural responses to previous female employment shocks.

Specifically, the paper includes the lagged value of the *maquiladora* employment share as an endogenous regressor in model (1.2) and use the lagged value of the shift-share instrument as an additional instrumental variable in both first-stage regressions. If indeed the divorce rate gradually adjusts to improvements in female labour market participation, one should observe a significant effect of the lagged shift-share instrument on the current divorce rate.

Column (1) of Table 1.15 presents the results from this exercise. The lagged value of the shift-share instrument has no significant effect over the female-instigated divorce rate on the grounds of domestic violence, but the effect of the current share on divorce is larger in the specification that accounts for dynamic behavioural effects than in the baseline IV model, suggesting that the baseline IV strategy underestimates the short-run role of female labour force participation in determining divorce decisions.

This result remains remarkably robust to a number modifications to the IV specification, presented in columns (2) through (5). Column (2) of the table presents the results when observations are weighted by the distance of the commuting zone to the US border. Column (3) shows the results when divorce rate outliers are removed from the sample. Column (4) displays the results from controlling for a large vector of time-varying covariates. Finally, Column (5) presents the results from controlling for linear-specific time trends in the divorce rate quarterly growth across commuting zones. In all cases, the lagged value of the shift-share instrument has no significant effect over the female-instigated divorce rate, while the current value of the *maquiladora* employment share significantly raises the divorce rate.

## 1.8 Conclusion

This paper studies the effects of improved female labour market access in Mexico on divorce rates between 1997 and 2006, using exogenous variation in female labour demand from an export manufacturing program that shelters the operations of large US companies in light industries. The paper finds that relative improvements to female earnings cause an increase in the number of divorces instigated by women on the grounds of domestic violence, consistent with an "empowerment" effect. This effect is particularly important for employed women with children within marriage. However, the paper also finds an increase in the homicide rate of married women, consistent with a "backlash" effect. These

[3] In a related contribution, Rasul (2005) studies how a shift from a mutual consent to a unilateral divorce regime might lead to an improvement of the quality match for newly formed marriages and therefore result in a reduction of the divorce rate in the long run.

results inform the policy discussion on the male-female earnings gap and the debate on female empowerment in developing countries, while emphasizing the importance of improving legal protection for women in developing countries. Additionally, this paper contributes to the literature documenting the benefits of free trade. Free trade has successfully raised female labour force participation and reduced male-female earnings differentials.

# Tables

Table 1.1: Summary statistics

| | 1997 | 1999 | 2001 | 2003 | 2005 |
|---|---|---|---|---|---|
| Population (thousands) | 521.2 | 606.7 | 667.5 | 711.2 | 758.6 |
| | (1423.3) | (1608) | (1660.2) | (1758.4) | (1806.2) |
| *Labour market characteristics* | | | | | |
| Average monthly earnings (2016 USD) | 349.5 | 351 | 365.2 | 374.3 | 383.1 |
| | (68.5) | (64.7) | (57.8) | (67.2) | (86.6) |
| Average within-household earnings gap (percent) | 46.4 | 44.7 | 45.6 | 45.2 | 48.5 |
| | (10.8) | (8.8) | (10.2) | (12.9) | (10) |
| *Maquiladora* | | | | | |
| Employees (thousands) | 13.4 | 16.6 | 14.4 | 14 | 15.9 |
| | (35.9) | (42.1) | (38.4) | (36.9) | (42.2) |
| Plants | 39 | 46 | 44 | 38 | 38 |
| | (104) | (120) | (117) | (96) | (98) |
| *Vital statistics* | | | | | |
| Divorce rate (per 100,000 individuals) | 30.6 | 27.8 | 29.6 | 31.3 | 31.7 |
| | (15.8) | (16.3) | (18) | (16.9) | (18.3) |
| *Crime* | | | | | |
| Domestic violence rate (per 100,000 individuals) | 0 | .02 | .15 | .4 | .61 |
| | (1.32) | (1.28) | (1.32) | (1.33) | (1.39) |
| Homicide of women rate (per 100,000 individuals) | .67 | .46 | .38 | .31 | .34 |
| | (.92) | (.65) | (.45) | (.35) | (.35) |

**Notes:** N=45 commuting zones. Statistics correspond to the last quarter of each year.

Table 1.2: Average characteristics of *maquiladora* and all other manufacturing plants in 2004

| Industry | Personnel by plant | | Percentage of female | | Hourly wage (2017 USD) | |
|---|---|---|---|---|---|---|
| | *Maquiladora* | All other | *Maquiladora* | All other | *Maquiladora* | All other |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| All | 381 | 13 | 49 | 35 | 4.26 | 2.69 |
| Textile | 331 | 15 | 55 | 54 | 4.44 | 1.57 |
| Shoes | 184 | 16 | 45 | 36 | 4.07 | 1.67 |
| Furniture | 174 | 7 | 31 | 18 | 4.44 | 1.48 |
| Chemical | 188 | 66 | 49 | 31 | 4.26 | 6.30 |
| Transports | 919 | 259 | 44 | 39 | 3.89 | 4.07 |
| Machinery | 293 | 42 | 41 | 19 | 4.35 | 3.43 |
| Electronics | 563 | 332 | 46 | 54 | 4.26 | 3.43 |
| Electrical | 512 | 166 | 53 | 37 | 4.35 | 3.52 |

**Notes:** Average characteristics of the *maquiladora* plants correspond to the administrative records of the program for 2004. Average characteristics for all other manufacturing plants were extracted from the economic census of 2004.

Table 1.3: Effect of the population share of women employed in the maquiladora program on the population share of employed women

*Dependent variables: population share of women employed in the maquiladora program (first stage) and population share of employed women (second stage)*

| | Baseline specification | | Covariates & | Time trends | | Covariate interactions | |
|---|---|---|---|---|---|---|---|
| | OLS | IV | Weights | Linear | Quadratic | Time trend | Time FE |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Second stage | | | | | | | |
| Female *maquiladora* share | .432 *** | .959 *** | .96 *** | .806 *** | 1.13 *** | .982 *** | .68 *** |
| | (.115) | (.109) | (.144) | (.17) | (.309) | (.173) | (.125) |
| Adjusted $R^2$ | .307 | . | . | . | . | . | . |
| First stage | | | | | | | |
| Shift-share instrument | | .13 *** | .142 *** | .138 *** | .129 *** | .142 *** | .109 *** |
| | | (.022) | (.024) | (.023) | (.026) | (.024) | (.006) |
| F-statistic (instr.) | | 23.2 | 33.3 | 34.4 | 19.4 | 33.7 | 215.2 |
| Adjusted $R^2$ | | .034 | .541 | .54 | .545 | .543 | .889 |

**Notes:** N=1575 (35 quarters $\times$ 45 commuting zones - 0 missing values). Standard errors are clustered at the commuting zone level and are robust to heterokedasticity. All regressions include commuting zone fixed effects and time dummies.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.4: Effect of the maquiladora employment share on local labour market outcomes by gender

| | Population shares | | | Log earnings (within household) |
|---|---|---|---|---|
| | Unemp./Inactive | Mfg | Non-Mfg | |
| | (1) | (2) | (3) | (4) |
| All individuals | -.759 *** | .164 | .593 *** | 2.709 *** |
| | (.165) | (.24) | (.174) | (.604) |
| | [-.018] | [.015] | [.013] | |
| Males | .202 | -.069 | -.139 | 1.333 ** |
| | (.293) | (.29) | (.16) | (.64) |
| | [.003] | [-.009] | [-.005] | |
| Females | -.96 *** | .233 *** | .732 *** | 1.786 *** |
| | (.144) | (.076) | (.071) | (.604) |
| | [-.012] | [.074] | [.043] | |
| Gender gap | 1.162 *** | -.303 | -.871 *** | -1.662 ** |
| | (.431) | (.35) | (.177) | (.738) |
| | [-.068] | [-.068] | [-.069] | |

**Notes:** N=1575 (35 years × 45 commuting zones - 0 missing values). All regressions control for a vector of covariates, commuting zone fixed effects, and time dummies. Observations are weighted by the reciprocal of the commuting zone distance to the US border. Standard errors are clustered at the commuting zone level and are robust to heterokedasticity. Numbers enclosed within brackets correspond to effects in percentage terms relative to the mean at baseline.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.5: Effect of a percentage point increase in the population share of women employed by the maquiladora program on divorce rates
*Dependent variable: rates per 1,000 individuals*

| | | | | |
|---|---|---|---|---|
| | *I. Divorce by gender of the instigator* | | | |
| | All | Mutual | Male | Female |
| | (1) | (2) | (3) | (4) |
| *Maquiladora* share | 1.07 | .051 | .192 | .828 ** |
| | (1.451) | (1.238) | (.336) | (.416) |
| | *II. Female-instigated divorce by separation cause* | | | |
| | Violence | Money | Abandonment | Adultery |
| | (1) | (2) | (3) | (4) |
| *Maquiladora* share | .158 *** | .288 *** | .419 | -.038 |
| | (.04) | (.076) | (.339) | (.028) |
| | *III. Female-instigated divorce by demographic group* | | | |
| | By empl. status of the wife | | By no. of children in marriage | |
| | Employed | Unemp/Inactive | No children | One or more |
| | (1) | (2) | (3) | (4) |
| *Maquiladora* share | .568 * | .26 | .125 | .703 ** |
| | (.312) | (.166) | (.128) | (.299) |

**Notes:** N=1567 (35 quarters × 45 commuting zones - 8 missing values). All regressions control for a vector of covariates, fixed effects and time dummies. Observations are weighted by the reciprocal of the commuting zone distance to the US border. Standard errors are robust and clustered at the commuting zone level.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.6: Effect of a percentage point increase in the maquiladora share on intimate partner violence
*Dependent variable: rates per 1,000 individuals*

| | *I. Domestic violence by empl. sector of the husband and drunkenness* | | | | |
|---|---|---|---|---|---|
| | All | Mfg | | Non-mfg | |
| | | Inebriated | Other | Inebriated | Other |
| | (1) | (2) | (3) | (4) | (5) |
| *Maquiladora* share | .049 | -.008 | .034 | .021 | .003 |
| | (.089) | (.04) | (.036) | (.029) | (.01) |
| | *II. Homicide of women by marital status of the victim* | | | | |
| | All | Single | Married | Separated from husband | Divorced |
| | (1) | (2) | (3) | (4) | (5) |
| *Maquiladora* share | .07 | -.097 | .23 *** | -.031 * | -.032 |
| | (.118) | (.065) | (.041) | (.018) | (.027) |

**Notes:** N=1575 (35 quarters × 45 commuting zones - 0 missing values). All regressions control for a vector of covariates, fixed effects and time dummies. Observations are weighted by the reciprocal of the commuting zone distance to the US border. Standard errors are robust and clustered at the commuting zone level.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.7: Effect of the population share of women employed by the maquiladora program on the variables of interest

| | Baseline | No outliers | No zeros | No cities |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Female employment share | .96 *** | .973 *** | .959 *** | .981 *** |
| | (.144) | (.159) | (.144) | (.138) |
| Female inst. divorce rate (violence) | .151 *** | .146 *** | .101 | .152 *** |
| | (.035) | (.033) | (.062) | (.036) |
| Homicide rate of married women per 1,000 | .23 *** | .232 *** | .311 *** | .231 *** |
| | (.041) | (.042) | (.09) | (.042) |

**Notes:** N=1575 (35 quarters × 45 commuting zones - 0 missing values). All regressions control for a vector of covariates, fixed effects and time dummies. Observations are weighted by the reciprocal of the commuting zone distance to the US border. Standard errors are clustered at the commuting zone level and are robust to heterokedasticity.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.8: Effect of the population share of women employed in the maquiladora program on the variables of interest

| | Baseline specification | | Covariates | Time trends | | Covariate interactions | |
|---|---|---|---|---|---|---|---|
| | OLS | IV | | Linear | Quadratic | Time trend | Time FE |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Female unemployment share | .432 *** | .959 *** | .96 *** | .806 *** | .914 *** | .96 *** | .68 *** |
| | (.115) | (.109) | (.144) | (.17) | (.219) | (.144) | (.125) |
| Female inst. divorce (violence) | .164 *** | .162 *** | .158 *** | .17 *** | .185 *** | .158 *** | .16 |
| | (.057) | (.06) | (.04) | (.047) | (.058) | (.04) | (.101) |
| Homicide rate of married women per 1,000 | .008 | .139 ** | .23 *** | .23 *** | .266 *** | .23 *** | .2 *** |
| | (.04) | (.057) | (.041) | (.044) | (.036) | (.041) | (.051) |

**Notes:** N=1575 (35 quarters $\times$ 45 commuting zones - 0 missing values). Standard errors are clustered at the commuting zone level and are robust to heterokedasticity. All regressions control for commuting zone fixed effects and time dummies.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.9: Placebo tests of the second-stage estimates

| | Baseline | Pre-opening outcome | Shift-share instrument | | |
|---|---|---|---|---|---|
| | | | Actual | Future | Difference (p-value) |
| | (1) | (2) | (3) | (4) | (5) |
| Female employment share | .136 *** | -.035 | .136 *** | .046 | .006 |
| | (.021) | (.042) | (.021) | (.03) | |
| Female inst. divorce rate (violence) | .022 ** | .007 | .022 ** | .013 | .507 |
| | (.01) | (.018) | (.01) | (.011) | |
| Homicide rate of married women | .017 * | -.002 | .017 * | .013 | .808 |
| | (.009) | (.005) | (.009) | (.022) | |

**Notes:** N=1575 (35 quarters × 45 commuting zones - 0 missing values). Standard errors are clustered at the commuting zone level and are robust to heterokedasticity. All regressions control for a vector of covariates, commuting zone fixed effects and time dummies.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.10: Effect of the population share of women employed by the maquiladora program on log population counts by demographic group
*Dependent variable: log population counts × 100*

| | All | Age group | | |
|---|---|---|---|---|
| | | Age 16-29 | Age 30-49 | Age 50-69 |
| | (1) | (2) | (3) | (4) |
| *Maquiladora* share | .04 | .91 | -1.48 | 1.36 |
| | (.91) | (.8) | (1.47) | (1.74) |
| | Gender | | Education | |
| | Male | Female | Non-college | College |
| | (5) | (6) | (7) | (8) |
| *Maquiladora* share | -.09 | .17 | -.59 | 4.2 |
| | (.71) | (1.15) | (.66) | (4.27) |

**Notes:** N=1575 (35 quarters × 45 commuting zones - 0 missing values). Standard errors are clustered at the commuting zone level and are robust to heterokedasticity. All regressions control for a vector of covariates, commuting zone fixed effects and time dummies. Observations are weighted by the reciprocal of the commuting zone distance to the US border.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.11: OLS and IV estimates of the effect of the population share of women employed by the maquiladora program on the female-instigated divorce rate on the grounds of domestic violence
*Dependent variable: divorce rates × 1,000*

| | No controls | Controls | Coefficients equal | Overid. test |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| OLS | .164 *** | .164 *** | [.939] | |
| | (.057) | (.056) | | |
| 2SLS (shift-share instrument) | .162 *** | .158 *** | [.45] | |
| | (.061) | (.059) | | |
| 2SLS (industry shares) | .12 ** | .119 ** | [.732] | 376.4 |
| | (.05) | (.052) | | [.933] |
| LIML (industry shares) | .114 ** | .113 ** | [.738] | 133.8 |
| | (.05) | (.052) | | [1] |
| MB2SLS (industry shares) | .1 ** | .098 * | [.89] | |
| | (.05) | (.052) | | |
| HFUL (industry shares) | .928 *** | .521 *** | [.613] | 393.7 |
| | (.05) | (.052) | | [.808] |

**Notes:** N=1567 (35 quarters × 45 commuting zones - 8 missing values). Column (1) reports the effect of *maquiladora* employment on the female-instigated divorce rate on grounds of domestic violence for each of the estimators proposed by Goldsmith-Pinkham, Sorkin and Swift (2018). Column (2) presents the resulting estimates when controlling for a lag of the outcome variable and vector of time-varying covariates. Column (3) presents the p-values corresponding to simple tests of differences in the coefficients in columns (1) and (2). Column (4) presents the scores an p-values from overidentification tests of the IV strategy. The 2SLS overidentification test is a Sargan (1958) test. The J-score for the LIML overidentification test comes from Cragg and Donald (1993). The J-statistic for the HFUL test comes from Chao, Hausman, Newey, Swanson and Woutersen (2014). All regressions include time dummies. Errors are clustered at the commuting zone level and are robust to heterokedasticity.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.12: Correlates of exposure to the maquiladora program at baseline
*Dependent variables: local share of national maquiladora employment by industry*

| Variable | Textile | Transp. | Electronic | Electric. | All other |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Distance to the US (hundreds of km) | -.002 | -.012 ** | -.009 ** | -.011 * | -.011 ** |
| | (.002) | (.006) | (.004) | (.006) | (.005) |
| Log population counts | | | | | |
| Total | -2.9 | 13.46 | 19.26 | 19.31 | 15.86 |
| | (11.06) | (18.32) | (13.23) | (17.36) | (15.31) |
| Female | 1.41 | -4.78 | -11.41 | -11.91 | -11.08 |
| | (7.01) | (10.47) | (8.15) | (10.95) | (10.2) |
| Male | 1.17 | -4.44 | -10.21 | -10.31 | -9.529 |
| | (6.43) | (9.31) | (7.29) | (9.73) | (9.04) |
| Aged 16-29 | .23 | -1.3 | .79 | 1.08 | 1.47 |
| | (1.22) | (1.42) | (1.15) | (1.78) | (1.8) |
| Aged 30-49 | .17 | -1.75 | .6 | 1.04 | 1.51 |
| | (1.32) | (1.5) | (1.21) | (1.89) | (1.93) |
| Aged 50 and over | .07 | -.4 | .2 | .34 | .45 |
| | (.35) | (.42) | (.36) | (.54) | (.55) |
| Divorce rate | .08 | .04 | .02 | -.02 | -.04 |
| | (.06) | (.06) | (.05) | (.06) | (.05) |
| Homicide rate of women | -.42 | -.48 | -1.29 | -.8 | -.54 |
| | (.52) | (1.03) | (1.21) | (1.44) | (1.19) |
| Violent crime rate | .01 | .06 | .1 | .17 | .17 |
| | (.04) | (.1) | (.07) | (.13) | (.14) |
| $N$ | 45 | 45 | 45 | 45 | 45 |
| $R^2$ | .2 | .39 | .53 | .45 | .48 |
| P-value ( $H_0 = \beta_2 = ... = \beta_K = 0$) | .333 | .387 | .66 | .898 | .82 |

**Notes:** Each column reports a separate cross-sectional regression of the local share of national *maquiladora* employment in a given industry on a set of commuting zone characteristics from the first quarter of 1998. Standard errors are robust to heterokedasticity.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.13: Industry-level regressions for the effect of the maquiladora employment share on female-instigated divorce on grounds of domestic violence, as in Borusyak et al. (2018)
*Dependent variables: shock to employment in thousands (first stage) and divorce rates per 1,000 individuals (second stage)*

| | Baseline | Covariates | AR(1) | Lagged outcome |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Second stage | | | | |
| *Maquiladora* share | .162 ** | .195 *** | .197 *** | -.092 |
| | (.08) | (.057) | (.059) | (.078) |
| First stage | | | | |
| Bartik instrument | .0644 *** | .0705 *** | .0703 *** | .0703 *** |
| | (.0108) | (.013) | (.0128) | (.0128) |
| Adjusted $R^2$ | .123 | .129 | .129 | .129 |
| F-statistic (instr.) | 35.5 | 29.4 | 30.1 | 30.1 |

**Notes:** N=480 (40 quarters × 12 industries - 0 missing values). Standard errors are clustered at the industry level and are robust to heterokedasticity.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.14: Correction of the standard errors for the effect of the population share of women employed by the maquiladora program on the female-instigated divorce rate on grounds of domestic violence
*Dependent variables: shock to employment in thousands (first stage) and divorce rates per 1,000 individuals (reduced form and second stage)*

| | First stage | Reduced form | Second stage |
|---|---|---|---|
| | (1) | (2) | (3) |
| $\beta$ | .13 | .022 | .162 |
| Cluster-robust | (.023) | (.01) | (.06) |
| AKM | (.003) | (.003) | (.025) |
| AKM0 | (.005) | (.003) | (.025) |

**Notes:** N=1567 (35 quarters × 45 commuting zones - 8 missing values). All regressions control for a vector of covariates, commuting zone fixed effects, and time dummies. Observations are weighted by the reciprocal of the US distance of the commuting zone to the US border. The AKM row presents standard errors elaborated as in equation (33) of Adão et al. (2018), whereas the AKM0 row presents standard errors with the null imposed, elaborated as in equation (26) of the same paper, but considering the extension for IV estimates.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.15: Multiple instrumentation: estimated impact of the populatioon share of women employed in the maquiladora program on female-instigated divorce on the grounds of domestic violence

*Dependent variables: population share of women employed in the maquiladora program (first stage) and female-instigated divorce rate per 1,000 individuals on the grounds of domestic violence (second stage)*

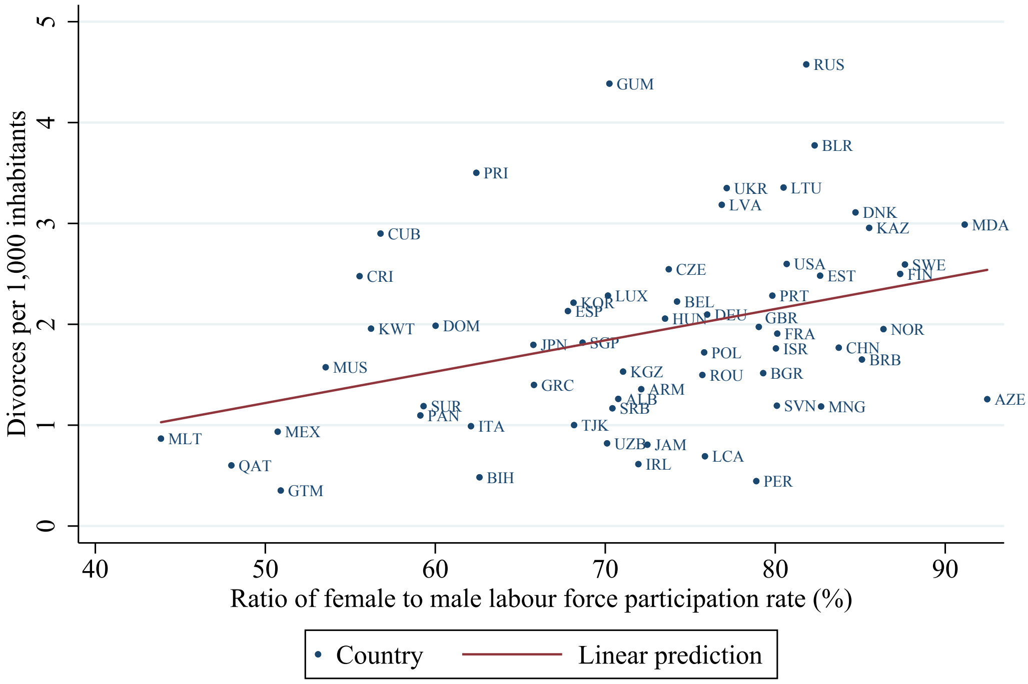
| | Baseline<br>(1) | Distance weights<br>(2) | No outliers<br>(3) | Controls<br>(4) | Linear trends<br>(5) |
|---|---|---|---|---|---|
| Second stage | | | | | |
| Current instrument only | .162 *** | .151 *** | .179 *** | .158 *** | .165 ** |
| | (.06) | (.036) | (.056) | (.058) | (.065) |
| Current and lagged instruments | .238 ** | .226 *** | .276 ** | .242 ** | .257 ** |
| | (.116) | (.058) | (.111) | (.12) | (.122) |
| First stages | | | | | |
| Kleinbergen-Paap rk LM stat. | 2.7 | 3.3 | 2.6 | 2.6 | 2.5 |
| | [.102] | [.071] | [.104] | [.11] | [.113] |
| Current maquiladora share | | | | | |
| Current instrument | .132 *** | .141 *** | .132 *** | .14 *** | .135 *** |
| | (.029) | (.028) | (.029) | (.029) | (.027) |
| Lagged instrument | .054 ** | .013 | .054 ** | .036 ** | .028 |
| | (.023) | (.028) | (.023) | (.017) | (.023) |
| F-statistic (instr.) | 54.5 | 32 | 55.41 | 29.5 | 24 |
| Lagged maquiladora share | | | | | |
| Current instrument | .048 *** | .033 ** | .049 *** | .049 *** | .046 *** |
| | (.009) | (.013) | (.01) | (.008) | (.008) |
| Lagged instrument | .122 *** | .127 *** | .121 *** | .122 *** | .126 *** |
| | (.024) | (.025) | (.024) | (.024) | (.024) |
| F-statistic (instr.) | 13.3 | 31.2 | 13.4 | 16.5 | 17 |
| Reduced form | | | | | |
| Current instrument | .03 *** | .031 *** | .034 *** | .03 *** | .031 ** |
| | (.012) | (.007) | (.008) | (.011) | (.012) |
| Lagged instrument | -.01 | -.017 | -.015 | -.009 | -.009 |
| | (.016) | (.016) | (.016) | (.019) | (.022) |

**Notes:** N=1567 (35 quarters $\times$ 45 commuting zones - 8 missing values). Standard errors are clustered at the commuting zone level and are robust to heterokedasticity. All regressions include commuting zone fixed effects and time dummies.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

## Figures

Figure 1.1: Divorce rates versus ratios of female to male labour force participation, 2012-2016



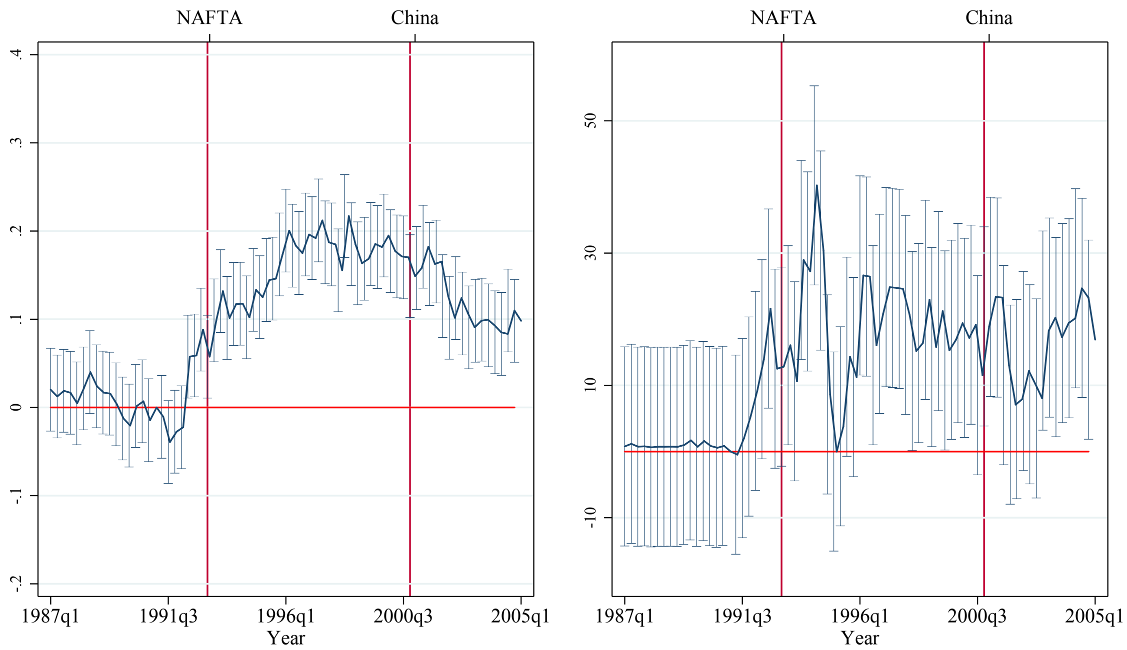

Divorce = -0.37 (0.711) - 0.03 (0.010) Ratio of female to male labour participation + ε

**Notes:** Each blue dot presents the average yearly divorce rate between 2012 and 2016 and the average ratio of female to male labour force participation in the same period for a different country. Data on divorce rates was obtained from the 2016 Demographic Yearbook of the UN, whereas data on the ratio of female to male labour force participation was obtained from the Gender Statistics Data Bank of World Bank. The red line presents the best linear predictor of the relationship between both variables.

Figure 1.2: Differences-in-differences graphs

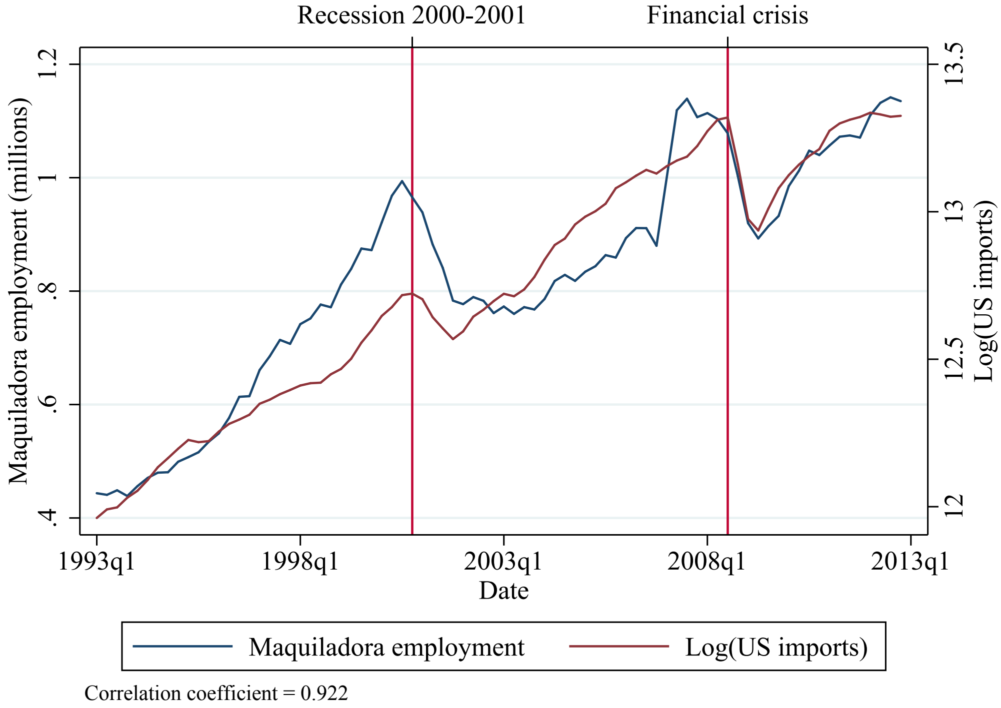
Panel (a). Female manufacturing share

Panel (b) Female-instigated divorce rate



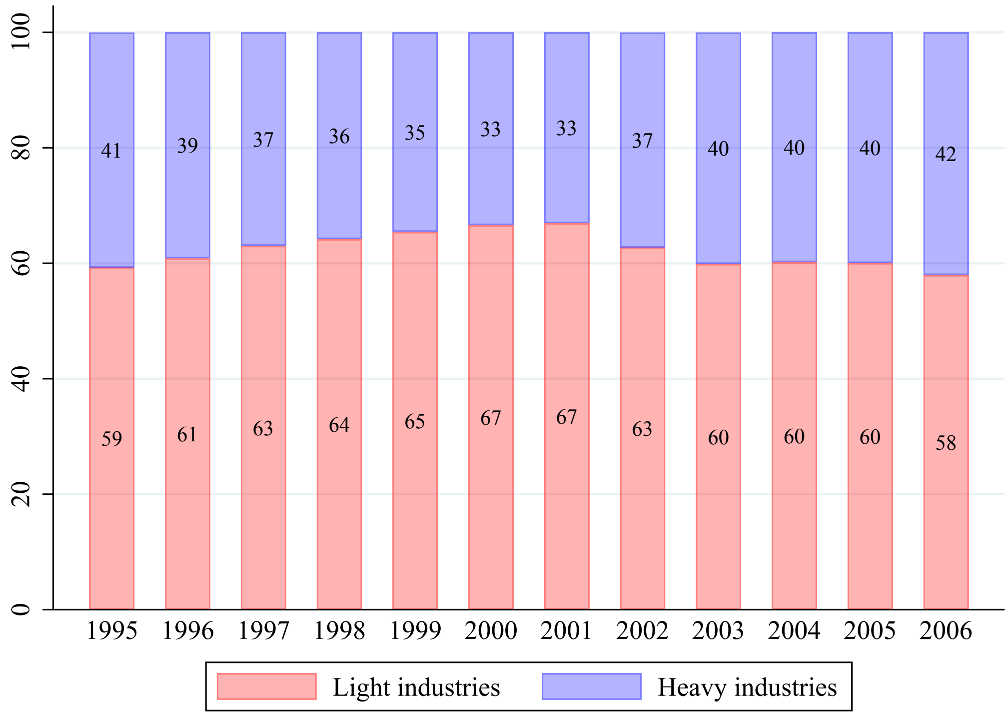

**Notes:** N= 792 (11 commuting zones $\times$ 72 quarters - 0 missing values). Confidence intervals are estimated using a wild cluster bootstrap procedure with 1,000 replicas to correct for the likely presence of Moulton bias. Each panel presents the point estimates and confidence intervals from a regression of a different outcome sector at the commuting zone level on *maquiladora* exposure at baseline interacted with time dummies. Each regression includes commuting-zone and time dummies. The first vertical red line in each panel represents the date of the signing of NAFTA, whereas the second red line depicts the date in which the US Congress granted Permanent Normal Trading Rights (PNTR) to China.

Figure 1.3: *Maquiladora* employment and US demand for imports, 1993-2012



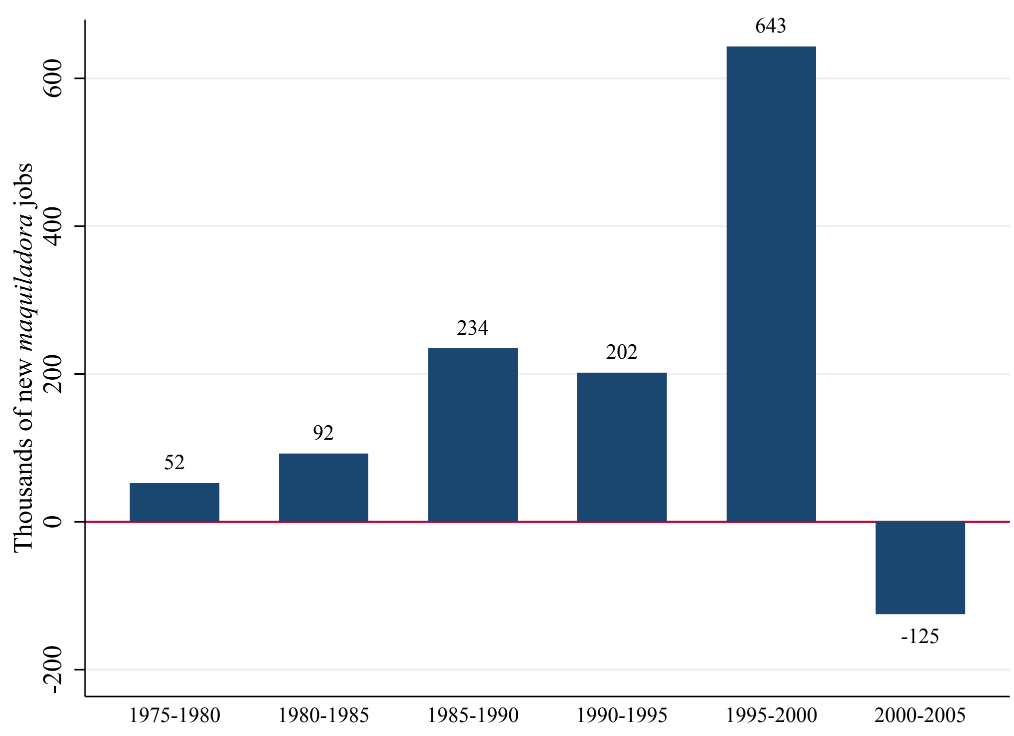

**Notes:** The blue line depicts the quarterly time-series for maquiladora employment at the national level, whereas the blue line shows the log of the demand for imports in the US, excluding Mexican imports.

Figure 1.4: *Maquiladora* employment shares by industry over time, 1995-2006



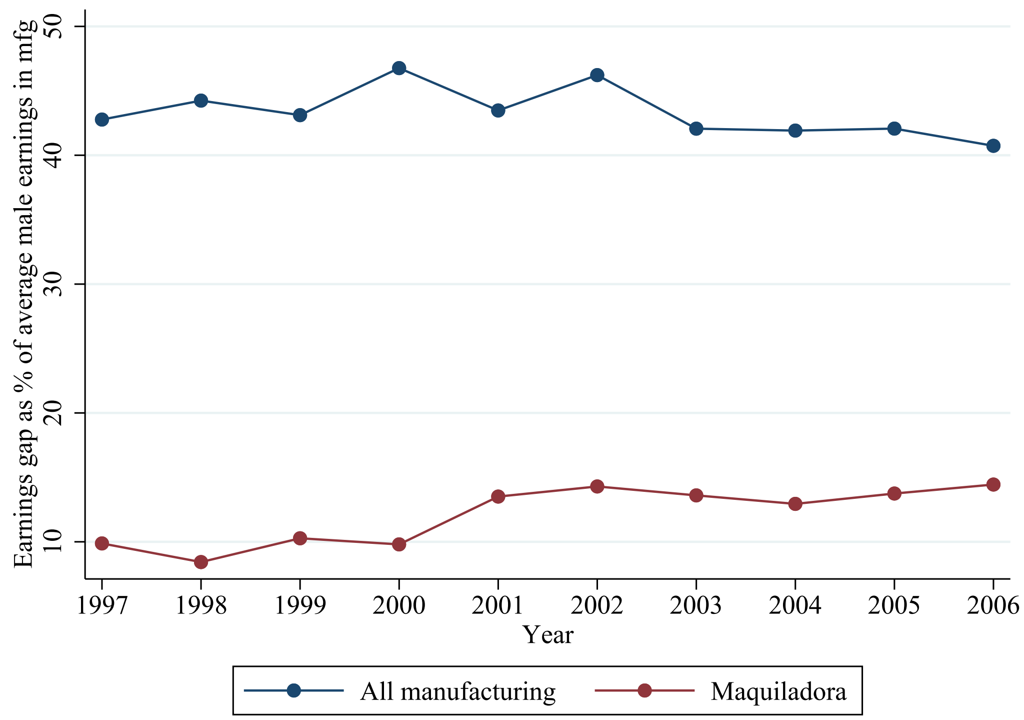

**Notes:** Heavy industries include heavy machinery, transports, furniture, electronics, and chemical materials. Light industries include food, garments, shoes, electric appliances, toys, and other industries.

Figure 1.5: Maquiladora employment over time



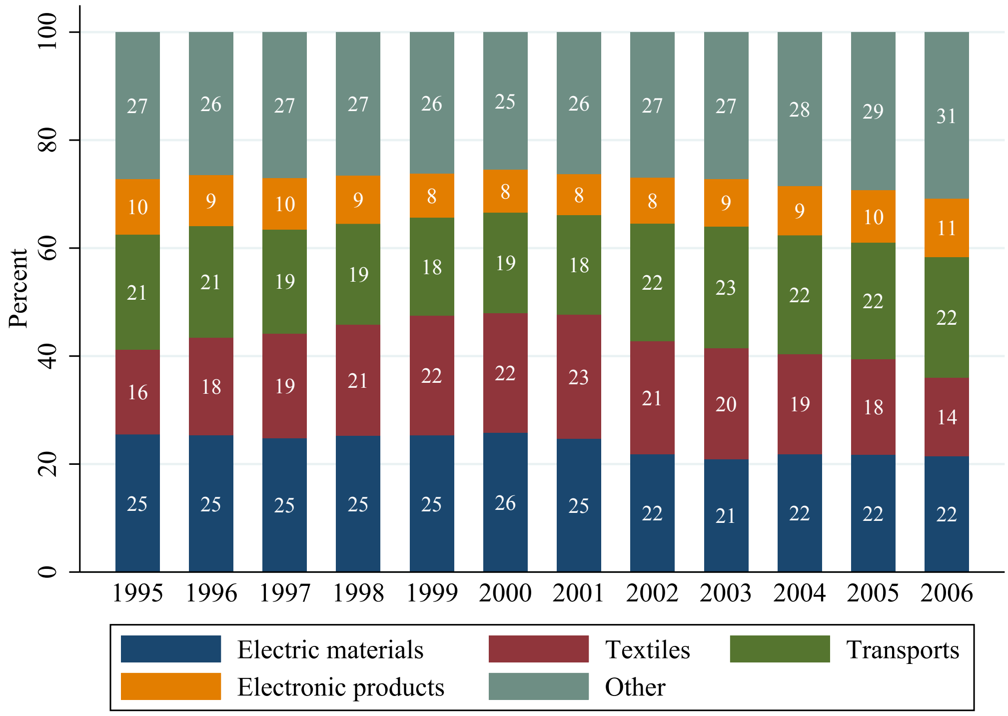

**Notes:** The figures show the number of new jobs created in each five-year period between 1975 and 2005, as measured by INEGI's administrative records of *maquiladora* employment.

Figure 1.6: Male-female earnings gap in the manufacturing sector, 1997-206



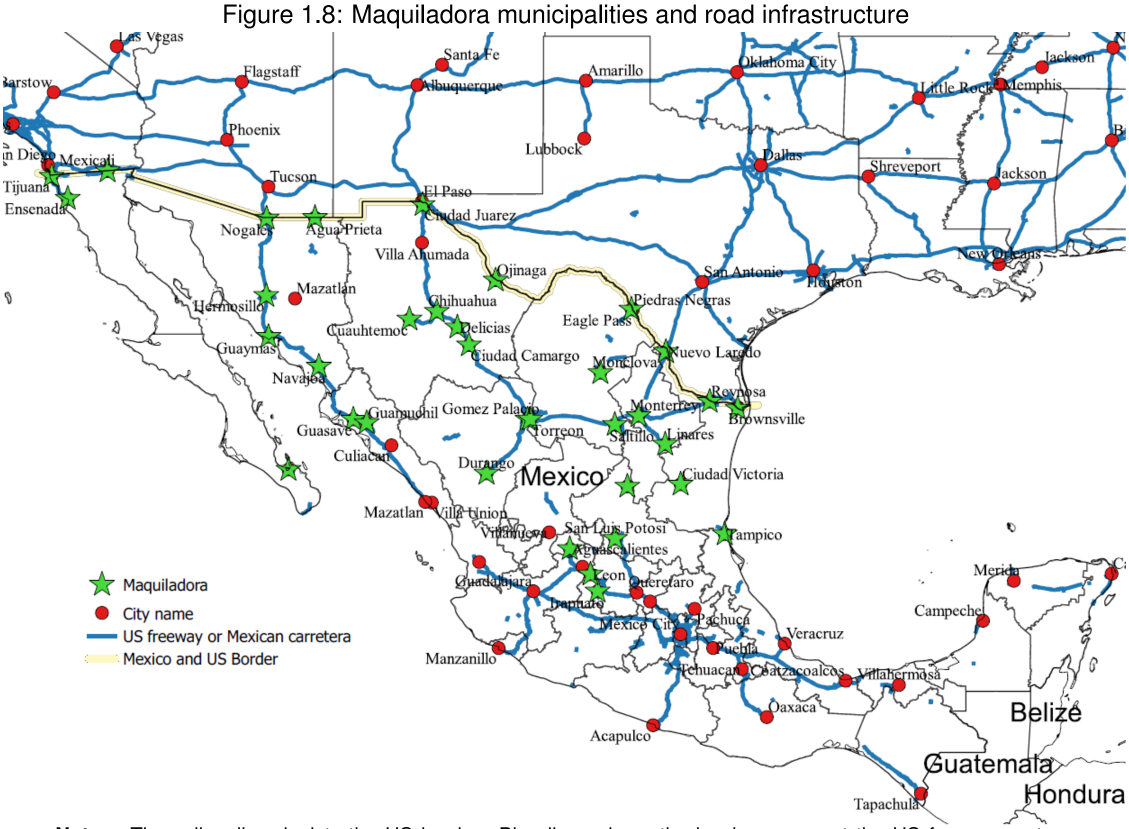

**Notes:** The red line represents the male-female earnings gap as a percentage of average male earnings within the *maquiladora* program, while the blue line represents the male-female earnings gap as a percentage of average male earnings in the manufacturing sector as a whole.

Figure 1.7: *Maquiladora* employment shares by industry



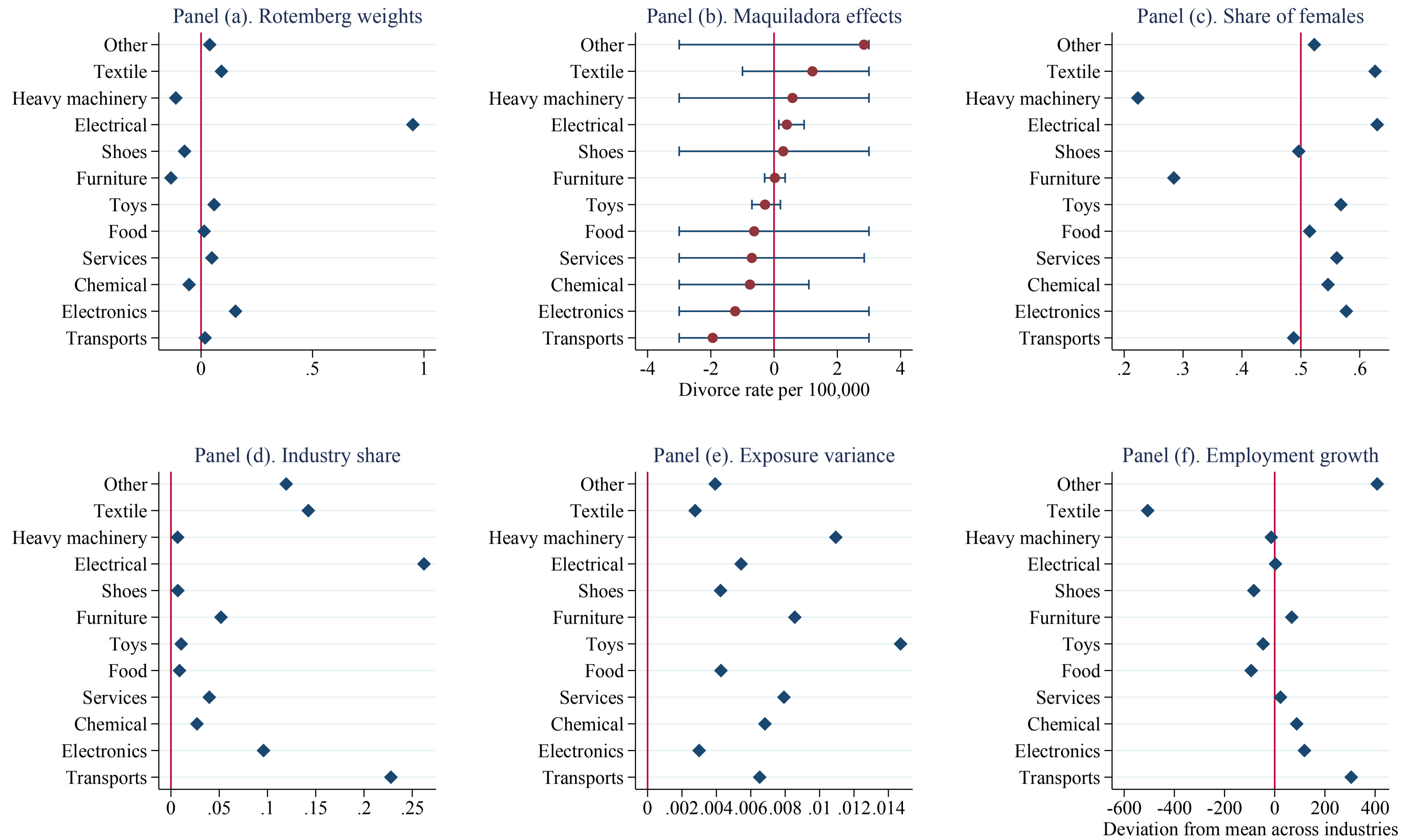

**Notes:** The bar "Other" represents employment in plants manufacturing food items, shoes, furniture, chemical products, heavy machinery, toys, and other products.

Figure 1.8: Maquiladora municipalities and road infrastructure




**Notes:** The yellow line depicts the US border. Blue lines above the border represent the US freeway system, whereas blue lines below the border represent Mexican *carreteras* of 2 lanes or more. Every red dot on the map accounts for a different city. The green stars denote municipalities exposed to the *maquiladora* program between 1990 and 2006. Layers containing American cities, roads, and state borders were retrieved from the CEC North America Environmental Atlas, whereas those containing Mexican cities, roads, and state borders correspond to INEGI's topography layers along with the *Marco Geoestadístico Nacional 2005*.

Figure 1.9: Summary statistics of Rotemberg weights, 1997-2006




**Notes:** Panel (a) depicts the *maquiladora* industry-specific effect on divorce rates. Point estimates come from just-identified 2SLS regressions, and 95 percent confidence intervals are estimated using the method from Chernozhukov and Hansen (2008) over a range of -100 to 100. Panel (b) describes the Rotemberg weights by industry. Panel (c) presents the average quarterly employment growth by industry relative the contemporaneous mean growth across all industries, or the average of $g_{k,t}$ taken over $t$. This figure depicts the evolution over time of the sum and the means of the Rotemberg weights across industries. Panel (d) shows the variance of initial exposure to *maquiladora* employment by industry across all commuting zones. Panel (e) presents the average employment share by industry over time. Panel (f) depicts the average share of female employees by industry.

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## A.1 Proofs of propositions in the main text

### A.1.1 Proof of Proposition 1

For part 1, multiply both sides of equation (1.2) by $\Delta S_{z,t}$ and take expectations. Then:

$$\begin{aligned}\beta &= \frac{E[\Delta Y_{z,t}\Delta S_{z,t}]}{E[\Delta S_{z,t}\Delta S_{z,t}]}\\ &= \frac{E[\Delta Y_{z,t}(\sum_{k=1}^{K}\Delta S_{z,t}^{k})]}{E[(\sum_{k=1}^{K}\Delta S_{z,t}^{k})(\sum_{k=1}^{K}\Delta S_{z,t}^{k})]}\\ &= \frac{E[\Delta Y_{z,t}(\sum_{k=1}^{K}\Delta S_{z,t}^{k})]}{\sum_{k=1}^{K}E[(\Delta S_{z,t}^{k})^2]}\\ &= \frac{\sum_{k=1}^{K}E[(\Delta S_{z,t}^{k})^2]\beta_k}{\sum_{k=1}^{K}E[(\Delta S_{z,t}^{k})^2]}\end{aligned}$$

The first equality follows from mean independence of $\Delta\varepsilon_{z,t}$ and $\Delta S_{z,t}$. The third equality follows from independence of *maquiladora* shocks across industries. The fourth equality equality follows from mean independence of $Y_{z,t}(\mathbf{0})$ and $\Delta S_{z,t}$.

For consistency,

$$\begin{aligned}V(\frac{1}{ZT}\sum_{z=1}^{Z}\sum_{t=1}^{T}\Delta S_{z,t}\Delta\varepsilon_{z,t}) &= \frac{1}{Z^2}\sum_{z=1}^{Z}V(\frac{1}{T}\sum_{t=1}^{T}\Delta S_{z,t}\Delta\varepsilon_{z,t})\\ &= \frac{1}{Z^2}\sum_{z=1}^{Z}\frac{1}{T}(2\sum_{j=1}^{T}\gamma_j(1-\frac{j}{T})+\gamma_0)\to 0 \text{ as } T\to\infty.\end{aligned}$$

Above, $\gamma_j$ denotes the $j$-th order auto-covariance of the $\Delta S_{z,t}\Delta\varepsilon_{z,t}$ process. The first equality follows from shock independence over $z$. Convergence to 0 follows from absolute summability of the $\Delta S_{z,t}\Delta\varepsilon_{z,t}$ process.

### A.1.2 Proof of Proposition 2

For part 1, multiply both sides of equation (1.2) by $\Delta B_{z,t}$ and take expectations. Then:

$$\begin{aligned}\beta &= \frac{E[\Delta Y_{z,t}\Delta B_{z,t}]}{E[\Delta S_{z,t}\Delta B_{z,t}]}\\ &= \frac{E[(\sum_{k=1}^{K}\Delta S_{z,t}^{k}\beta_k)\Delta B_{z,t}]}{E[\Delta S_{z,t}\Delta B_{z,t}]}\\ &= \frac{E[(\sum_{k=1}^{K}\Delta S_{z,t}^{k}\beta_k)\Delta B_{z,t}]}{E[(\sum_{k=1}^{K}\Delta S_{z,t}^{k})\Delta B_{z,t}]}\\ &= \frac{\sum_{k=1}^{K}E[\Delta S_{z,t}^{k}\Delta B_{z,t}]\beta_k}{\sum_{k=1}^{K}E[\Delta S_{z,t}^{k}\Delta B_{z,t}]}.\end{aligned}$$

The first equality follows from mean independence of $\Delta\varepsilon_{z,t}$ and $\Delta M_t^k\ \forall k\in\{1,2,...,K\}$, and the second inequality follows from mean independence of $\Delta Y_{z,t}(\mathbf{0})$ and $\Delta M_t^k\ \forall k\in\{1,2,...,K\}$.

For consistency,

$$
\begin{aligned}
V(\frac{1}{ZT}\sum_{z=1}^{Z}\sum_{t=1}^{T}\Delta B_{z,t}\Delta\varepsilon_{z,t}) &= \frac{1}{Z^2}\sum_{z=1}^{Z}V(\frac{1}{T}\sum_{t=1}^{T}\Delta B_{z,t}\Delta\varepsilon_{z,t}) \\
&= \frac{1}{Z^2}\sum_{z=1}^{Z}V(\frac{1}{T}\sum_{t=1}^{T}(\sum_{k=1}^{K}\chi_z^k\Delta M_t^k)\Delta\varepsilon_{z,t}) \\
&= \frac{1}{Z^2}\sum_{z=1}^{Z}\sum_{k=1}^{K}(\chi_z^k)^2 V(\frac{1}{T}\sum_{t=1}^{T}\Delta M_t^k\Delta\varepsilon_{z,t}) \\
&= \frac{1}{Z^2}\sum_{z=1}^{Z}\sum_{k=1}^{K}(\chi_z^k)^2\frac{1}{T}(2\sum_{j=1}^{T}\delta_j^k(1-\frac{j}{T})+\delta_0^k) \to 0 \text{ as } T\to\infty.
\end{aligned}
$$

Above, $\delta_j^k$ denotes the $j$-th order auto-covariance of the $\Delta M_t^k\Delta\varepsilon_{z,t}$ process $\forall k\in\{1,2,...,K\}$. The first equality follows from shock independence over $z$. Convergence to 0 follows from absolute summability of the $\Delta M_t^k\Delta\varepsilon_{z,t}$ process.

### A.1.3 Proof of Proposition 3

Without loss of generality, consider industry $k$. For part 1, multiply both sides of equation (1.2) by $\chi_z^k\Delta M_t^k$ and take expectations. Then:

$$
\begin{aligned}
\delta_k &= \frac{E[\Delta Y_{z,t}\Delta M_t^k]}{E[\Delta S_{z,t}\Delta M_t^k]} \\
&= \frac{E[(\sum_{j=1}^{K}S_{z,t}^j\beta_k)\Delta M_t^k]}{E[\Delta S_{z,t}\Delta M_t^k]} \\
&= \frac{E[(\sum_{j=1}^{K}S_{z,t}^j\beta_j)\Delta M_t^k]}{E[(\sum_{j=1}^{K}S_{z,t}^j)\Delta M_t^k]} \\
&= \frac{\sum_{j=1}^{K}E[S_{z,t}^j\Delta M_t^k]\beta_j}{\sum_{j=1}^{K}E[S_{z,t}^j\Delta M_t^k]}
\end{aligned}
$$

The first equality follows form mean independence of $\Delta\varepsilon_{z,t}$ and $\Delta M_t^k$. The second inequality follows from mean independence of $\Delta Y_{z,t}(\mathbf{0})$ and $\Delta M_t^k$.

For consistency,

$$
\begin{aligned}
V(\frac{1}{ZT}\sum_{z=1}^{Z}\sum_{t=1}^{T}\Delta M_z^k\Delta\varepsilon_{z,t}) &= \frac{1}{Z^2}\sum_{z=1}^{Z}V(\frac{1}{T}\sum_{t=1}^{T}\Delta M_z^k\Delta\varepsilon_{z,t}) \\
&= \frac{1}{Z^2}\sum_{z=1}^{Z}\frac{1}{T}(2\sum_{j=1}^{T}\delta_j(1-\frac{j}{T})+\delta_0) \to 0 \text{ as } T\to\infty.
\end{aligned}
$$

Above, $\delta_j$ denotes the $j$-th order auto-covariance of the $\Delta M_t^k\Delta\varepsilon_{z,t}$ process. The first equality follows from shock independence over $z$. Convergence to 0 follows from absolute summability of the $\Delta M_t^k\Delta\varepsilon_{z,t}$ process.

# Chapter 2

# Property Tax Compliance in Developing Countries: Evidence from Mexico

*"The amount of crime is determined not only by the rationality and preferences of would-be criminals but also by the economic and social environment created by public policies"* (Becker, 1993)

## 2.1 Introduction

The property tax is one of the most important sources of revenues for local governments in countries around the world (Slack, 2013). Revenues from this source can serve as a tool for redistribution and public good provision, especially in contexts of high inequality. Nevertheless, property tax revenues are low as a share of GDP, especially in low and middle-income countries. These countries typically raise less than 0.5% of GDP in property taxes, compared to 2.1% in high income countries, partly due to criminal "non-compliance" resulting from imperfect enforcement coupled with the fact that property taxes are not withheld at source but are instead paid directly by taxpayers in periodic lump sums (Sepulveda and Martinez-Vazquez, 2012).

This paper studies the effect of increasing the tax rate over time as a policy measure to improve local revenues in contexts where imperfect enforcement enables taxpayers to decide whether to comply with the tax liability. In particular, the paper uses administrative tax records from over one million residential properties in Mexico City to estimate the elasticity of tax compliance to the tax rate. Findings indicate that this elasticity is negative but relatively small, between -0.15 and -0.37. Hence, further tax rate increases would improve tax revenues because the mechanical increase in the liabilities of taxpayers surpasses the behavioural reduction in compliance.

The paper leverages variation in tax rates over time, stemming from the gradual and unannounced removal of long-lasting tax rate reductions, which were specific to some cadastral value brackets. Specifically, tax rates are set on a yearly basis at the value bracket level (see Figure 2.1). This paper uses the unexpected tax rate jumps experienced by brackets I, H and G in 2010, 2011 and 2012 respectively as a source of exogenous variation in tax rates. Importantly, property valuation remains constant during the time of our study, allowing us to isolate the effect of shifts in the tax rate.

The empirical analysis of this paper relies on property-level cadaster and tax payment records from the universe of residential properties in Mexico City between 2008 and 2013. The key outcome of interest is the compliance share, defined as the tax liability paid divided by the tax liability owed (for a fiscal year), and three different empirical methodologies are used in estimation: a semi-parametric method that builds counterfactual compliance by excluding the treated range, in the spirit the "bunching" literature; a regression discontinuity design exploiting tax rate variation around the lower limit of the treated brackets; and a differences-in-differences strategy that compares properties in treated brackets to other properties before and after the tax discount removals. These different empirical methodologies enable the analysis of short- and long-run compliance responses.

Results indicate that most increases in the tax rate lead to reductions in compliance, although the implied elasticities are relatively small for smaller rate changes. Depending on the empirical method, the compliance elasticity estimate by the most modest tax rate change is between -0.15 and -0.25. For the larger rate change in tax bracket G, which experiences a 43% increase in the tax rate, the compliance elasticity is between -0.31 and -0.37. In all cases under study, the reduction in compliance is too small to reverse the mechanical effect of the higher tax rate, and total tax revenues increase.

These results imply that current property tax rates are below the revenue-maximizing Laffer rate, even in the highest tax brackets. However, from an equity perspective, policy makers need to take into account that a rate increase also increases inequality within tax brackets, as only a subset of dutiful taxpayers continue to comply with their liability when the tax rate increases. Thus, higher rates should be combined with more targeted enforcement to prevent this worsening in compliance inequality.

This paper relates to several connected literatures. First, there is a large literature (reviewed in Saez, Slemrod and Giertz 2012) estimating the elasticity of taxable income, considered the key parameter to determine welfare maximizing tax rates. This elasticity is often a combination of evasion, avoidance and real responses, though real responses are rare among firms. For property taxes, the tax base is evaluated only every few years (or only every few decades in low-capacity settings), so that the primary behavioural response to the tax is in terms of payment compliance. Thus, this paper identifies the compliance elasticity as the key parameter determining the revenue-maximizing tax rate and provides a consistent estimate of this elasticity.

Second, this study relates to a large literature on tax compliance (reviewed in Slemrod 2007). Most of these studies focus on the reporting margin (e.g. Slemrod 2001, Pomeranz 2015, Naritomi 2016), and more recently on the tax filing margin (Brockmeyer et al., forthcoming). This paper argues that, for the property tax, payment compliance is the crucial margin to consider, as taxpayers cannot adjust the tax base in the short term. While the effect of a tax rate increase on compliance is theoretically ambiguous, the results from this study echo Kleven, Knudsen, Kreiner, Pedersen and Saez (2011) and Fisman and Wei (2004) in showing that an increase in the tax rate reduces tax compliance.

Third, this study contributes to a small but growing literature on property taxation in lower income countries, where this tax is vastly underexploited. Del Carpio (2014) studies the effect of social norms on property tax compliance in Peru and Okunogbe (forthcoming) tests the impact of improved enforcement capacity in Liberia. Khan, Khwaja and Olken (2015) test the impact of performance incentives on tax inspectors in the context of property taxation in Pakistan. In most developing countries, compliance is low and policy makers need to decide whether to invest in enforcement or change tax rates or both. The results in this study suggest that increasing tax rates might yield higher revenues even in high evasion contexts, as the compliance elasticity with respect to the tax rate is modest.

The rest of the paper is structured as follows. Section 2 presents the property tax system in Mexico City and the source of experimental variation. Section 3 describes the data used for the empirical analysis, consisting of the property cadaster and payment records. Section 4 presents the empirical strategy. Section 5 reports the results and discusses the mechanisms driving them. Section 6 concludes.

## 2.2 Context

This section briefly describes a number of regulations governing the levy of property taxes in Mexico City before turning to the analysis of the effect of the tax rate on tax compliance. In particular, the following subsections describe the main aspects of the regulation on property valuation and yearly tax rates, as well as the regulation pertaining to the timing of payments, tax enforcement, and the possibility that taxpayers have of filing a complaint to modify their tax liability. The section concludes by explaining the sources of exogenous variation used for estimation in the paper.

### 2.2.1 Cadastral value determination

The cadastral value of property $i$ in year $t$ is estimated by the local government as follows:

$$V_{i,t} = (A_{i,t}L_{i,t} + U_{i,t}M_{i,t})[1 - D_t \cdot (\mathbb{1}_{\{t-t_0 \leq 40\}}(t-t_0) + \mathbb{1}_{\{t-t_0>40\}}40)],$$

where $V_{i,t}$ is the cadastral value of the property, $A_{i,t}$ is the unit value of the land in the neighbourhood of property $i$ (based on the commercial value of the neighbouring area per square meter, which are seldom updated by the government), $L_{i,t}$ is the total land area of the property, $U_{i,t}$ is the unit value of construction in the neighbourhood of property $i$ (based on the commercial value per square meter), $M_{i,t}$ is the total construction area of the property, $D_t$ is a yearly reduction applied per each year of antiquity, and $t_0$ is the year of the construction of the property. Essentially, cadastral value is the sum of land and construction value, and property value falls with antiquity, up until the moment the property becomes 40 years old.

### 2.2.2 Tax rates and the tax base

In general terms, the tax liability of each property in Mexico City is determined based on its cadastral value, which is estimated–as discussed above–through an official valuation that takes into consideration the commercial values in the neighbouring area, as well as the longevity of the property and its land and construction area. Importantly, cadastral values were not updated during the period under study (see Figure 2.2), so this paper interprets them as a time-invariant characteristic of properties when conducting the empirical analysis.

Given the cadastral value of the property, according to local legislation, the yearly tax liability is determined as follows:

$$L_{i,t} = F_t(B_{i,t}) + [V_{i,t} - \text{Inf}(B_{i,t})] \cdot \tau_t(B_{i,t})$$

where $L_{i,t}$ is the bi-monthly liability of property $i$ in year $t$, $B_{i,t}$ is the cadastral value band of property $i$, $F_t(B)$ is the lump-sum liability corresponding to the cadastral value band $B$, Inf$(B)$ is the cadastral value lower limit of the value band $B$, and $\tau_t(B)$ is the marginal tax rate for properties in $B$.

The property tax schedule is published on a yearly basis in the fiscal code of Mexico City and contains cadastral value bands, the value intervals, and the marginal tax rate function. Tables 2.1 through 2.6 show the property tax schedules for years between 2008 and 2013.

### 2.2.3 Timing of payments

Once the yearly tax liability is determined, taxpayers make the payment of the yearly liability in 6 bi-monthly instalments. Each instalment is due on the last day of the second month of the bi-monthly period. However, properties have the option of paying the whole yearly liability all-in-once (all six bimesters of the running year) before a specified date. Early payment entitles taxpayers to a so-called “early-bird” or a super-“early bird” discount. These early bird discounts vary across years, as shown by Table 2.7. Usually, payments of the full yearly liability made by the last day of January qualify for the super-“early-bird” discount, whereas payments made by the last day of February qualify only for the “early-bird” discount.

### 2.2.4 Taxpayer complaints

Starting on 2006, taxpayers can reject the cadastral valuation proposed by the government, and instead propose their own self-reported valuation. Self-reported valuations are elaborated as follows. The taxpayer reports land area, construction area, and other characteristics of the property to an online government system. Then, the system then uses official valuation tables of land area, construction area, and other property characteristics to estimate the cadastral value of the property. If the government agrees with the new valuation calculated by the online system, a new, corrected liability is issued by the tax administration office. In practice, very few taxpayer complaints result in successful manipulation of the tax liability, as discussed in subsequent sections.

### 2.2.5 Enforcement

This subsection details (1) the enforcement faculties of the local tax administration authorities and (2) the surcharges, penalty fees, and collection costs applied to overdue tax payments. First, enforcement sanctions applied by the local government to delinquent taxpayers depend on the severity of the fault perpetrated by the taxpayer. In principle, purposeful omission, either partial or total, of payment of a tax liability is punishable with up to 10 years of prison according to the local fiscal code. Moreover, both discretionary investigation of evasion and judicial seizures of the properties of delinquent taxpayers are within the local government faculties. However, in practice, investigation of taxpayer delinquency is largely determined by human resource constraints.

Second, concerning liability augmentation applied to taxpayers making payments after the bimonthly deadline, the government automatically updates all unpaid liabilities for inflation on a monthly basis. Furthermore, the government also automatically charges a surcharge for late payment to the taxpayer for every month of late payment. This surcharge is a fraction of the value of the liability which varies with inflation but is usually around 1%. For example, if a taxpayer makes an overdue payment after 6 months, the government adds a 6% surcharge to the updated liability. Moreover, taxpayers that have not yet completed payment of the yearly liability by the 30th of April of the subsequent fiscal year are automatically catalogued as delinquent taxpayers, which are subject to even harsher enforcement measures. In particular, whenever a delinquent taxpayer is prosecuted by the local tax administration, she has a grace period to comply with full payment and, if payment is made after this grace period, the liability augments anywhere between 10 and 90%, depending on the discretionary judgement of the tax authority. Finally, in the extreme case in which the government seizes the property to repair the damage generated by lack of payment, it charges the taxpayer with part of the collection costs, usually setting them at 2% of the value of the overdue liability. A brief summary of the average liability augmentations to delinquent properties in 2008 and 2009 is presented in Table 2.11.

### 2.2.6 Sources of exogenous variation

This section describes the sources of variation in tax rates used to break-up the correlation between compliance and tax rates, which one would expect to arise from the fact that the government has an incentive to impose higher rates on delinquent households. Specifically, the paper uses the timing of the removal of long-lived tax discounts, originally introduced before 1990, at the cadastral value band level. The removal of these abatements took place in a staggered fashion without announcement of this policy measure to the affected cadastral value bands prior to the publication of this policy measure in the fiscal code of the year in turn. The purpose of the removal of the tax abatements was purely that of increasing tax revenues after the onset of the international financial crisis. Indeed, Figure 2.3 shows that property tax revenues dramatically increase after 2008 in Mexico City.

Table 2.8 presents the tax abatements by cadastral value band and year between 2008 and 2013 as a percentage of the total yearly liability. In 2008, cadastral value bands E through J were subject to a substantive discount to the value of their liability, ranging from 65 percent for value band E to 10 percent for value band J.

In 2009, the tax abatement for cadastral band J was removed, but properties in this value band were still eligible for this discount for an additional year if they filed a complaint at the closest regional tax administration office. This "optional" removal of the tax abatement is indicated with grey in the table. From 2010 onwards, the tax abatement for value band J was completely removed.

The removal of the tax abatement for band "I" was implemented in a similar fashion. Up until 2009, all properties in this value band were subject to a tax discount of 15 percent to their liability. At the beginning of 2010, the tax abatement was removed, but households in this band were still eligible for the discount for an additional year if they filed the corresponding complaint. Once again, this "optional" removal of the tax abatement is indicated with grey in the table. Finally, the tax abatement was completely removed in years 2011 through 2013.

Next, the tax abatement of 20 percent for the cadastral value band H was implemented in 2011, with an "optional" removal that lasted of one year leading to a full removal in years 2012 and 2013. The timing of this policy measure is also indicated with grey in the table.

The tax abatement removal for value band G was implemented in 2012, but was different to the rest of the previous abatements because the removal was only partial in nature. That is, starting on 2012, the tax abatement went from 30 percent of the value of the liability to only 20 percent. As before, individuals filing a complaint at a regional tax administration office were still eligible to benefit from the 30 percent discount for an additional year, but an inferior discount of 20 percent became mandatory in 2013.

The abovementioned tax abatement removals act as a source of differential treatment by year and cadastral value band, used as part of the empirical strategy to provide causal estimates of the effect of the tax rate on tax compliance, as well as to break-up the correlation between compliance and tax rates that is likely to arise endogenously. Additional sources of changes in the tax rate are (1) unexpected changes in marginal rates across value bands and (2) yearly changes in the lump-sum liabilities of lower-value properties. Details on these additional sources of variation are provided in figures 2.5 and 2.6. However, these sources of variation are not used in our analysis because they induce negligible differences in the value of tax liabilities over time, which are unlikely to be noticed by taxpayers or generate a strong behavioural response.

## 2.3 Data

### 2.3.1 Dataset construction

To conduct the empirical analysis, this study uses data on the complete property tax records of Mexico City between 2009 and 2012. These data, provided to the World Bank by the local ministry of finance, includes records of more than one million residential properties. Available variables include a property identifier, along with several characteristics of the property, such as area, value, and tax liability. This data is used to construct a balanced panel of properties that includes more than 95 percent of the total number of properties in the original dataset.

Moreover, the dataset includes information on all property tax payments at the property level on a bi-monthly basis. Using these administrative records of tax payments, the paper constructs the following variables at the property level with a yearly frequency for the empirical analysis: (1) payment amount in current MXN thousands and (2) the compliance share, defined as the ratio of payment to the gross liability.

In addition to the above variables, micro-data on tax payments is used to construct other secondary indicators that are useful for the interpretation of our empirical results. Namely, data on the amount of the tax payment relative to the total tax liability is used to construct dummies for zero, partial, and full payment. Furthermore, the paper exploits the date of payment to construct dummies pertaining to the timing of payments. Specifically, dummies for early (all-in-once), bi-monthly, and late payment are constructed. Finally, information on the modality of payment is used to construct a dummy of payments made after a tax complaint was filed by the taxpayer.

### 2.3.2 Summary statistics

This subsection presents a selected group of relevant summary statistics of the dataset. One of the most salient features of the data is that the distribution of properties by value band is heavily skewed towards low-value bands, whereas the fiscal load is much more evenly distributed across the whole range property values. These features of the panel of residential properties in Mexico City are shown in Figure 2.4. Panel (a) of this figure shows the distribution of properties by value band, with the majority of properties falling inside bands A through E. Panel (b) presents the cadastral value distribution, which is also heavily skewed towards low-value bands. Panel (c) depicts the distribution of tax liabilities. Even though the majority of all properties fall within brackets A through E, the distribution of liabilities is spread evenly across all cadastral value brackets. Panel (d) depicts the revenues distribution, which are also evenly distributed.

Next, a broader set of property characteristics are described in tables 2.9 and 2.10. In particular, the table summarizes (1) time-invariant characteristics of the properties, including property land, construction area, and year of construction; (2) time-varying characteristics of the properties, such as yearly tax liabilities and tax rates; and (3) variables pertaining to the payments data that were described above.

A couple of salient features of the data are worth mentioning. First, concerning the time-invariant characteristics, the average property was built in 1985, having an average land area of 123 square meters and an average construction area of 126 squared meters. Second, since cadastral values were not updated by the government during the period under consideration (with the important exception of an update for inflation between 2008 and 2009), the overwhelming majority of the variation in tax liabilities–which exhibits a notoriously increasing trend–is explained by a sustained increase in the mean tax rate over time. In contrast to this increasing trend in tax rates, data reveals a suggestive drop in the average amount of tax payment over time, not only in absolute terms but also as a share of the yearly liability. Relatedly, the share of properties making zero payment grows over time, while the share of properties making the full payment falls, and the share of properties making a partial payment displays an increasing trend until 2010 and a decreasing trend afterwards. The reduction in the compliance share is also reflected in the early payment share and in the share of payments made after filing a complaint.

## 2.4 Empirical strategy

This section describes the empirical strategy used to estimate the elasticity of tax compliance to the tax rate. First, for the study of short-term compliance responses, the text lays out two different methodologies: (1) a semi-parametric method in the spirit of the “bunching” literature, and (2) a regression discontinuity design, both of which allow for non-linearities in the elasticity of tax compliance to the tax rate. Next, the paper turns to describe a differences-in-differences strategy, which allows for measurement of long-run effects on tax compliance. Throughout, the paper uses the unexpected removal of tax abatements as a source of exogenous variation in the tax rate. As discussed before, these tax abatements were specific to some cadastral value brackets and were initially introduced more than 20 years before their removal.

### 2.4.1 Semi-parametric estimation

The paper proposes first a semi-parametric methodology to measure the responses of taxpayers to changes in the tax rate in the short run. A potential concern with an entirely parametric model is that the response of compliance to the tax rate might be non-linear. Intuitively, taxpayers might respond differentially to tax rate changes of different magnitudes. For instance, a mild increase in the tax rate might lead to no change in compliance, as the liability is not sufficiently burdensome make the household divert resources towards consumption, but an unjustified drastic increase in the tax rate might make consumption relatively more attractive than compliance.

Specifically, to determine whether responses of taxpayers to changes in the tax rate are essentially nonlinear, the paper implements the following semi-parametric methodology, in the spirit of Chetty (2009). Grouping properties into cadastral value bins indexed by $j$, the counterfactual distribution of changes in compliance is estimated in the following form:

$$\Delta C_j = \sum_{i=0}^{5} \beta_i (V_j)^i + \sum_{i=V_-}^{V_+} \gamma_i \mathbb{1}\{V_j = i\} + \varepsilon_j,$$

where $\Delta C_j$ is the average change in compliance of properties in bin $j$, $V_j$ is the average cadastral value of properties in bin $j$, and $[V_-, V_+]$ is the cadastral value range affected by the removal of tax abatements.

The counterfactual change in compliance is obtained by omitting the contribution of the dummies in the excluded range (i.e., $\Delta\hat{C}_j = \sum_{i=0}^{5} \beta_i (V_j)^i$). That is, the fifth-order polynomial that gives the best fit to changes in average tax compliance, when excluding the treated cadastral value range, provides counterfactual compliance, against which compliance in the range of values affected by the removal of tax abatements is compared.

Specifically, excess compliance is estimated as the average difference between the observed and counterfactual compliance changes in the bins affected by the removal of the tax abatements, or:

$$\hat{B} = \frac{\sum_{j=V_-}^{V_+} (\Delta C_j - \Delta\hat{C}_j)}{\sum_{j=V_-}^{V_+} 1}.$$

Standard errors around the point estimate are calculated by using a bootstrap procedure in which 100 compliance change distributions are generated by random resampling of the residuals $\varepsilon_j$.

Finally, bins are created by ordering properties according to their cadastral value within each of the cadastral value bands defined by the tax authority and then grouping the total number of properties within each band into equally-sized bins. Since different cadastral value bands contain different numbers of properties, the number of bins constructed by the paper within value bands depends on the number of properties in the cadastral value band. In particular, let $K$ be the number of bins in a cadastral value band of $N$ properties. The rule $K = \alpha \log\left(\frac{N}{\beta}\right)$ is used, where $\alpha$ and $\beta$ are arbitrarily chosen coefficients that satisfy the equalities $5 = \alpha \log\left(\frac{10{,}000}{\beta}\right)$ and $1 = \alpha \log\left(\frac{200}{\beta}\right)$. This rule imposes the condition that a cadastral value band with 10,000 properties should have 5 bins, as well as the condition that a value band with only 200 properties should have only 1 bin. Note that the above function is concave and increasing in $N$, so the number of bins will always be close to 5, even for value bands with a large number of properties.

### 2.4.2 Regression discontinuity design: an alternative

To build confidence around the estimates resulting from the above semi-parametric method, the paper implements a regression discontinuity design (RDD), by leveraging the discontinuity in the probability of treatment around the cadastral value band thresholds defined by the local tax authority. In particular, for each year under consideration, the paper gathers individual-level tax compliance indicators for both the treated band and the band located immediately below in terms of value. Then, these data is used for estimation via local regression.

In particular, let $\Delta Y_i$ denote yearly change in the outcome of interest for property $i$. The effect of a tax abatement removal on the compliance indicator of interest is given by the $\beta$ in the following model:

$$\Delta Y_i = \alpha + \beta T_i + \sum_{p=1}^{3} \gamma_p (V_i - V_-)^p + \sum_{p=1}^{3} \delta_p (V_i - V_-)^p T_i + \varepsilon_i,$$

where $V_-$ is the cadastral value threshold above which property $i$ is treated with an increase in the tax rate, and $T_i$ is a dummy taking the value of 1 if property value is greater than or equal to the threshold, or $V_i > V_-$. The identifying assumption required for consistency of $\beta$ is that the “counterfactual” or “potential” compliance is uncorrelated with the assignment criterion. This assumption is likely to hold if households cannot directly manipulate their property valuation in response to a change in the tax rate. On the other hand, if households were able to manipulate property valuation successfully, changes in tax compliance around the threshold could reflect, for example, a movement of the most “conscientious” households into the comparison band.

### 2.4.3 Long-term dynamics: differences-in-differences

Both of the empirical methods introduced above allow for consistent estimation, even in the presence of non-linearities in the response of compliance to the tax rate, but they capture only short-run responses. A tax rate hike could result in a short-lived drop in payment fading away after the household gathers sufficient liquidity to pay overdue liabilities. To address this possibility, the paper proposes a simple differences-in-differences specification, comparing the individual-level compliance indicators, before and after treatment, of properties in the treated cadastral value band to those of properties in other high-value bands that were never treated with a tax abatement removal.

Specifically, let $Y_{i,t}$ denote a relevant tax compliance outcome of property $i$ in year $t$. The long run effect of the tax abatement removal in year $t_0$ on the outcome of interest is given by $\beta$ in the following model:

$$\Delta Y_{i,t} = \alpha + DD_{i,t}\beta + \gamma_i + \delta_t + \varepsilon_{i,t},$$

where $\alpha$ is a constant, $DD_{i,t}$ is a dummy taking the value of 1 when property $i$ belongs to the treated cadastral value band and $t \geq t_0$, $\delta_t$ denotes a year effect, $\gamma_i$ denotes a property-specific fixed effect, and $\varepsilon_{i,t}$ denotes a mean zero error term. Consistent estimation of the parameter $\beta$ via fixed effects estimation requires the identifying assumption $E[\varepsilon_{i,t}|DD_{i,t}] = 0$. Essentially, the above identifying assumption amounts to asserting that the timing of the tax abatement removal is uncorrelated with any other unobservable determinant of compliance. Additionally, the identifying assumption requires that the outcome of interest in the treated and control properties display parallel trends during the pre-treatment period.

A slightly more sophisticated model allows for the existence dynamic effects. In particular, the effect of a tax abatement removal $j$ periods after implementation in $t_0$ on the outcome of interest is given by $\beta_j$ in the following model:

$$Y_{i,t} = \alpha + \sum_{j=-\infty}^{\infty} DD_{i,t+j}\beta_j + \gamma_i + \delta_t + \varepsilon_{i,t},$$

where $DD_{i,t+j}$ is a dummy taking the value of 1 when property $i$ belongs to the treated cadastral value band and $t+j=t_0$. Once again, the identifying assumption is that $E[\varepsilon_{i,t}|DD_{i,t+j}]=0$ for all $j \in \mathbb{Z}$, which amounts to asserting that the timing of treatment is uncorrelated with unobservable determinants of the outcome of interest. Additionally, the parallel trends assumption of $\beta_j = 0$ for all $j \in \mathbb{Z}^-$ can be formally tested using a simple F-test. Next, the paper turns to estimation in the results section.

## 2.5 Results

This section presents the effect of the tax abatement removals described in section 2.2.6 on four indicators of interest: the mean tax rate; yearly payment amount; a dummy for payment of the whole yearly liability at once; and the compliance share, defined as the ratio of the payment amount to the yearly tax liability. The section begins by presenting the short-run estimates resulting from the semi-parametric method. Next, the paper turns to describe the regression discontinuity design estimates as an alternative methodology. Finally, the text provides a summary of the estimates resulting from the differences-in-differences specification described above.

### 2.5.1 Semi-parametric estimation

Figure 2.8 provides a visual representation of the results from the semi-parametric estimation method. Each graph within the figure presents both the observed and counterfactual changes for a different indicator-year combination. In each graph, properties within a cadastral value band are grouped into different bins, and both the number of bins and their size depends in turn on the total number of properties within the cadastral value band. For each year, the treated band is highlighted in grey, and the effect of the tax abatement removal is given by the average vertical distance between the observed change and the counterfactual change in the compliance indicator for the bins in in the grey area.

The first row of the figure presents the effect of the tax discount removal for properties in bracket I in 2010. Panel (a) depicts a strongly significant increase in the mean tax rate of 8.73 basis points. This increase in the mean tax rate is accompanied by an improvement of the payment amount of 410 Mexican pesos on average, as shown by Panel (b). Nevertheless, Panel (c) shows that the removal of the tax discount also lowers the number of taxpayers paying at once their yearly liability by 3.56 percentage points. Similarly, the compliance share falls by 1.21 percentage points, as shown in Panel (d).

The second row of the figure presents the effect of an even steeper tax discount removal for properties in bracket H in 2011. This time, the mean tax rate increases by 11.8 basis points, and payment improves by 830 Mexican pesos, but the number of taxpayers complying at once with their yearly liability falls by 6.94 percentage points, and the compliance share falls by 2.18 percentage points.

Panels (a) through (d) in the third row of the figure present the effect of the steepest tax discount removal, which took place in 2012 and affected properties in bracket G. The mean tax rate increased by a striking 17.55 basis points, but average payment improved by only 690 Mexican pesos, even less than with the tax increase that affected the adjacent bracket the year before. Indeed, the number of taxpayers that complied at once with their yearly liability fell by 10.26 percentage points, while the compliance share fell by 5.95 percentage points.

Hence, the effect of increasing the tax rate on compliance appears to become steeper with the size of the change in the tax rate. Table 2.12 rigorously measures this regularity, by estimating the elasticities of the outcomes of interest with respect to the mean tax rate[1]. Of particular interest is the magnitude of the elasticity of the compliance share with respect to the mean rate. Column (4) of the table shows that the magnitude of the elasticity ranges from -0.145 when the size of the tax rate change is 8.73 to -0.31 when the size of the tax rate change is 17.55. A formal t-test rejects the null of equality between both elasticities.

### 2.5.2 Regression discontinuity design

An alternative identification strategy leverages variation in the tax rate around the lower limit of the treated cadastral value brackets. Figure 2.9 provides visual evidence of compliance discontinuities around these lower limits. Each graph within a row of the figure displays the average yearly change in a different outcome before and after treatment for 20 equally spaced bins. Each graph in the figure also depicts a fitted third-order polynomial for the yearly change in the outcome of interest, using control and treatment units separately. Additionally, 95 percent confidence intervals for the fitted polynomials are highlighted in grey.

The first row of the figure depicts yearly changes in the indicators of interest between 2009 and 2010 around the lower limit of bracket I. Panel (a) highlights a sharp increase in the mean tax rate arising as a consequence of the discount removal, consistent with a strongly significant local regression estimate of 11.73 basis points, while Panel (b) shows that payment also increased, consistent with a statistically significant effect on payment of 935 Mexican pesos. These estimates are greater in magnitude than those obtained through the semi-parametric method, but run in the same direction. In contrast, panels (c) and (d) show that the number of taxpayers complying at once with their yearly liability fell by 4.42 percentage points and that the compliance share fell by 2.75, although these latter estimates are not significant.

The second row of the figure presents yearly changes in the outcomes of interest between 2010 and 2011 around the lower limit of bracket H. Once again, Panel (a) depicts a sharp increase in the mean tax rate of 15.68 basis points, but this time payment improves only by 1,055 Mexican pesos on average, as shown in Panel (b). This finding is consistent with a significant 5.55 percentage points reduction in the number of taxpayers complying at once with their yearly tax liability, as well as with a non-significant reduction in the compliance share of 2.29 percentage points, both of which are depicted in panels (c) and (d).

The third row of the figure presents yearly changes between 2011 and 2012 around the lower limit of bracket G. The removal of the discount results in a stunning increase of 22.62 basis points in the tax liability, which is accompanied by a modest increase in payment of 805 Mexican pesos on average. In turn, the removal of the discount reduces both the number of people complying at once with their yearly liability and the compliance share, by 13.2 and 7.94 percentage points respectively. All these effects are strongly significant, indicating that more aggressive increases in the tax rate also result in more pronounced tax compliance responses.

Table 2.13 presents the implied elasticities for the indicators of interest with respect to the tax rate, which are remarkably similar to those obtained using the semi-parametric methodology. Importantly, the implied elasticities of the compliance share are shown in column (4). When the change in the mean tax rate is 11.73 basis points, the compliance elasticity estimate of -0.245 is non-significant, whereas the estimate of -0.321 is strongly significant when the tax rate increases by 22.62 basis points, indicating that the removal of the tax discount reduces welfare only when the change in the tax rate is sufficiently high. A formal t-test, however, does not reject the null of equality between elasticities.

As mentioned above, the validity of these estimates crucially depends on the assumption that taxpayers cannot directly manipulate their property valuation in response to a change in the tax rate.

[1] Elasticities are calculated using the elasticity formula $\varepsilon_{y,t} = \frac{\partial y}{\partial t}\frac{t}{y}$, where $\frac{\partial y}{\partial t}$ is taken from the semi-parametric estimates, and $\frac{t}{y}$ is calculated using the outcome means at baseline.

To formally test for this possibility, this paper conducts the robustness checks proposed by McCrary (2008), which consist of testing for discontinuities in the distribution of the running variable around the treatment cut-off. Figure 2.10 shows the results from these tests. This paper fails to reject the null hypothesis of no manipulation of property values around the treatment cut-offs.

### 2.5.3 Differences-in-differences

Figure 2.11 presents differences-in-differences graphs that enable the study of the dynamic effects of tax discount removals. In each row, the effects of a different discount removal are considered, and each panel within a row depicts the trajectory of a different outcome. In each graph, the vertical black line represents the moment of treatment, the red line represents the average outcome of interest in the treated bracket relative to its pre-treatment mean, and the blue line represents the average outcome in the control group. In all graphs, the control group is composed of properties belonging to the high-value cadastral value bands K and L, which were never treated with a tax rate increase.

The first row of the figure shows the effects of the discount removal that affected bracket I in 2010. The numerical differences-in-differences estimate indicates a strongly significant increase in the mean tax rate of 19.3 percent relative to baseline, and Panel (a) reveals that the increase was sustained over time. However, the differences-in-differences numerical estimate shows that the average payment improved by only 13.4 percent, not nearly as much as the tax rate increase, and, moreover, Panel (b) suggests that payment falls over time. This finding is consistent with a reduction in the number of taxpayers complying at once with their yearly tax liability by 10.3 percent relative to baseline, as well as with a drop in compliance of 3.6 percent relative to baseline. Indeed, panels (c) and (d) depict reductions in tax compliance.

The finding that compliance falls more sharply with more aggressive changes in the tax rate, highlighted in previous sections, continues to hold when using differences-in-differences. As shown by the second row of the figure, the discount removal that affected bracket H in 2011 increased the mean tax rate by 27.3 percent relative to baseline and improved the payment amount by 16.7 percent, while reducing payment in full by 15.2 percent and curtailing the compliance share by 6.3 percent. On the other hand, the third row of the figure reveals that the removal of the tax discount that affected bracket G in 2012 increased the tax rate by a stunning 46.8 percent relative to baseline and improved the average payment amount by only 15.6 percent, while reducing payment in full by a striking 30.3 percent and curtailing the compliance share by 17.1 percent.

Table 2.14 calculates the elasticity of each outcome with respect to the tax rate by taking the ratio of the effect of the discount removal on the outcome of interest to its effect on the mean tax rate. In particular, the elasticity of tax compliance with respect to the tax rate is presented in column (4) of the table, ranging from -0.186 in response to a 19.3 percent increase in the tax rate affecting bracket I in 2010, to -0.366 in response to a 46.8 percent increase in the tax rate affecting bracket G in 2012. A formal t-test rejects the null hypothesis of equality between the two elasticities. These figures are remarkably similar to those resulting from semi-parametric estimation, as well as those from regression discontinuity design.

## 2.6 Discussion and concluding remarks

This paper studies the optimal design of property tax schedules in a context of low compliance and high inequality. The paper uses tax records from over one million properties in Mexico City to study the effect of increasing the mean tax rate over time to improve local tax revenues in contexts of weak enforcement. Identification of the effect of the tax rate on compliance is enabled by variation in tax rates over time, stemming from the unexpected removal of long-lasting tax abatements which were specific to some cadastral value brackets. Results indicate that the compliance elasticities are between -0.15 and -0.37. These findings imply that the discount removals increase tax revenues but cause reductions in compliance, emphasizing the importance of improving tax enforcement in addition to implementing tax rate hikes in developing countries.

# Tables

Table 2.1: Bi-monthly tax rate determination in 2008

| Band | Cadastral value lower limit (MXN) (1) | Cadastral value upper limit (MXN) (2) | Lump-sum liability (MXN) (3) | Tax rate on excess from lower limit (4) | Percent discount on liability (5) |
|---|---|---|---|---|---|
| A | 0.11 | 153,196.67 | 30 | 0 | 0 |
| B | 153,196.68 | 306,392.88 | 35 | 0 | 0 |
| C | 306,392.89 | 612,786.93 | 42 | 0 | 0 |
| D | 612,786.94 | 919,179.80 | 52 | 0 | 0 |
| E | 919,179.81 | 1,225,573.85 | 694.06 | 0.0009542 | 65 |
| F | 1,225,573.86 | 1,531,966.73 | 986.42 | 0.0011091 | 45 |
| G | 1,531,966.74 | 1,838,359.59 | 1,326.24 | 0.0011461 | 30 |
| H | 1,838,359.60 | 2,144,753.66 | 1,677.39 | 0.0012522 | 20 |
| I | 2,144,753.67 | 2,451,146.53 | 2,061.06 | 0.0013097 | 15 |
| J | 2,451,146.54 | 2,757,540.60 | 2,462.34 | 0.0013478 | 10 |
| K | 2,757,540.61 | 3,063,933.46 | 2,875.30 | 0.0013892 | 0 |
| L | 3,063,933.47 | 3,370,326.34 | 3,300.94 | 0.001427 | 0 |
| M | 3,370,326.35 | 3,677,012.18 | 3,738.17 | 0.0015075 | 0 |
| N | 3,677,012.19 | 11,031,035.35 | 4,200.50 | 0.0016278 | 0 |
| O | 11,031,035.36 | 23,217,399.31 | 16,171.38 | 0.0016286 | 0 |
| P | 23,217,399.32 | | 36,018.10 | 0.0016902 | 0 |

Table 2.2: Bi-monthly tax rate determination in 2009

| Band | Cadastral value lower limit (MXN) (1) | Cadastral value upper limit (MXN) (2) | Lump-sum liability (MXN) (3) | Tax rate on excess from lower limit (4) | Percent discount on liability (5) |
|---|---|---|---|---|---|
| A | 0.11 | 162,740.82 | 32 | 0 | 0 |
| B | 162,740.83 | 325,481.16 | 37 | 0 | 0 |
| C | 325,481.17 | 650,963.56 | 45 | 0 | 0 |
| D | 650,963.57 | 976,444.70 | 55 | 0 | 0 |
| E | 976,444.71 | 1,301,927.10 | 737.28 | 0.0009542 | 65 |
| F | 1,301,927.11 | 1,627,408.26 | 1,047.86 | 0.0011091 | 45 |
| G | 1,627,408.27 | 1,952,889.39 | 1,408.85 | 0.0011461 | 30 |
| H | 1,952,889.40 | 2,278,371.81 | 1,781.88 | 0.0012522 | 20 |
| I | 2,278,371.82 | 2,603,852.96 | 2,189.45 | 0.0013097 | 15 |
| J | 2,603,852.97 | 2,929,335.38 | 2,615.73 | 0.0013478 | 10 |
| K | 2,929,335.39 | 3,254,816.51 | 3,054.42 | 0.0013892 | 0 |
| L | 3,254,816.52 | 3,580,297.67 | 3,506.58 | 0.001427 | 0 |
| M | 3,580,297.68 | 3,906,090.04 | 3,971.04 | 0.0015075 | 0 |
| N | 3,906,090.05 | 11,718,268.85 | 4,462.17 | 0.0016278 | 0 |
| O | 11,718,268.86 | 24,663,843.29 | 17,178.84 | 0.0016286 | 0 |
| P | 24,663,843.30 | | 38,262.00 | 0.0016902 | 0 |

Table 2.3: Bi-monthly tax rate determination in 2010

| Band | Cadastral value lower limit (MXN) (1) | Cadastral value upper limit (MXN) (2) | Lump-sum liability (MXN) (3) | Tax rate on excess from lower limit (4) | Percent discount on liability (5) |
|---|---|---|---|---|---|
| A | 0.11 | 162,740.82 | 34 | 0 | 0 |
| B | 162,740.83 | 325,481.16 | 39 | 0 | 0 |
| C | 325,481.17 | 650,963.56 | 48 | 0 | 0 |
| D | 650,963.57 | 976,444.70 | 58 | 0 | 0 |
| E | 976,444.71 | 1,301,927.10 | 778.35 | 0.0010074 | 65 |
| F | 1,301,927.11 | 1,627,408.26 | 1,106.23 | 0.0011709 | 45 |
| G | 1,627,408.27 | 1,952,889.39 | 1,487.32 | 0.0012099 | 30 |
| H | 1,952,889.40 | 2,278,371.81 | 1,881.13 | 0.0013219 | 20 |
| I | 2,278,371.82 | 2,603,852.96 | 2,311.40 | 0.0013827 | 15 |
| J | 2,603,852.97 | 2,929,335.38 | 2,761.43 | 0.0014229 | 0 |
| K | 2,929,335.39 | 3,254,816.51 | 3,224.55 | 0.0014666 | 0 |
| L | 3,254,816.52 | 3,580,297.67 | 3,701.90 | 0.0015065 | 0 |
| M | 3,580,297.68 | 3,906,090.04 | 4,192.23 | 0.0015914 | 0 |
| N | 3,906,090.05 | 11,718,268.85 | 4,710.71 | 0.0017185 | 0 |
| O | 11,718,268.86 | 24,663,843.29 | 18,135.70 | 0.0017193 | 0 |
| P | 24,663,843.30 | | 40,393.19 | 0.0017844 | 0 |

Table 2.4: Bi-monthly tax rate determination in 2011

| Band | Cadastral value lower limit (MXN) (1) | Cadastral value upper limit (MXN) (2) | Lump-sum liability (MXN) (3) | Tax rate on excess from lower limit (4) | Percent discount on liability (5) |
|---|---|---|---|---|---|
| A | 0.11 | 162,740.82 | 35 | 0 | 0 |
| B | 162,740.83 | 325,481.16 | 41 | 0 | 0 |
| C | 325,481.17 | 650,963.56 | 50 | 0 | 0 |
| D | 650,963.57 | 976,444.70 | 60 | 0 | 0 |
| E | 976,444.71 | 1,301,927.10 | 810.11 | 0.0010484 | 65 |
| F | 1,301,927.11 | 1,627,408.26 | 1,151.36 | 0.0012186 | 45 |
| G | 1,627,408.27 | 1,952,889.39 | 1,548.00 | 0.0012593 | 30 |
| H | 1,952,889.40 | 2,278,371.81 | 1,957.88 | 0.0013759 | 20 |
| I | 2,278,371.82 | 2,603,852.96 | 2,405.71 | 0.0014391 | 0 |
| J | 2,603,852.97 | 2,929,335.38 | 2,874.10 | 0.0014809 | 0 |
| K | 2,929,335.39 | 3,254,816.51 | 3,356.11 | 0.0015264 | 0 |
| L | 3,254,816.52 | 3,580,297.67 | 3,852.94 | 0.0015679 | 0 |
| M | 3,580,297.68 | 3,906,090.04 | 4,363.27 | 0.0016564 | 0 |
| N | 3,906,090.05 | 11,718,268.85 | 4,902.91 | 0.0017886 | 0 |
| O | 11,718,268.86 | 24,663,843.29 | 18,875.64 | 0.0017895 | 0 |
| P | 24,663,843.30 | | 42,041.23 | 0.0018575 | 0 |

Table 2.5: Bi-monthly tax rate determination in 2012

| Band | Cadastral value lower limit (MXN) (1) | Cadastral value upper limit (MXN) (2) | Lump-sum liability (MXN) (3) | Tax rate on excess from lower limit (4) | Percent discount on liability (5) |
|---|---|---|---|---|---|
| A | 0.11 | 162,740.82 | 36 | 0 | 0 |
| B | 162,740.83 | 325,481.16 | 42 | 0 | 0 |
| C | 325,481.17 | 650,963.56 | 52 | 0 | 0 |
| D | 650,963.57 | 976,444.70 | 62 | 0 | 0 |
| E | 976,444.71 | 1,301,927.10 | 839.27 | 0.0010862 | 65 |
| F | 1,301,927.11 | 1,627,408.26 | 1,192.81 | 0.0012625 | 45 |
| G | 1,627,408.27 | 1,952,889.39 | 1,603.73 | 0.0013046 | 30 |
| H | 1,952,889.40 | 2,278,371.81 | 2,028.36 | 0.0014255 | 0 |
| I | 2,278,371.82 | 2,603,852.96 | 2,492.32 | 0.0014909 | 0 |
| J | 2,603,852.97 | 2,929,335.38 | 2,977.57 | 0.0015342 | 0 |
| K | 2,929,335.39 | 3,254,816.51 | 3,476.93 | 0.0015814 | 0 |
| L | 3,254,816.52 | 3,580,297.67 | 3,991.65 | 0.0016244 | 0 |
| M | 3,580,297.68 | 3,906,090.04 | 4,520.35 | 0.001716 | 0 |
| N | 3,906,090.05 | 11,718,268.85 | 5,079.41 | 0.001853 | 0 |
| O | 11,718,268.86 | 24,663,843.29 | 19,555.16 | 0.0018539 | 0 |
| P | 24,663,843.30 | | 43,554.71 | 0.0019243 | 0 |

Table 2.6: Bi-monthly tax rate determination in 2013

| Band | Cadastral value lower limit (MXN) (1) | Cadastral value upper limit (MXN) (2) | Lump-sum liability (MXN) (3) | Tax rate on excess from lower limit (4) | Percent discount on liability (5) |
|---|---|---|---|---|---|
| A | 0.11 | 162,740.82 | 38 | 0 | 0 |
| B | 162.740.83 | 325,481.16 | 44 | 0 | 0 |
| C | 325,481.17 | 650,963.56 | 54 | 0 | 0 |
| D | 650,963.57 | 976,444.70 | 64 | 0 | 0 |
| E | 976,444.71 | 1,301,927.10 | 874.1 | 0.0011313 | 50 |
| F | 1,301,927.11 | 1,627,408.26 | 1,242.31 | 0.0013149 | 35 |
| G | 1,627,408.27 | 1,952,889.39 | 1,670.28 | 0.0013588 | 25 |
| H | 1,952,889.40 | 2,278,371.81 | 2,112.54 | 0.0014846 | 0 |
| I | 2,278,371.82 | 2,603,852.96 | 2,595.75 | 0.0015527 | 0 |
| J | 2,603,852.97 | 2,929,335.38 | 3,101.14 | 0.0015979 | 0 |
| K | 2,929,335.39 | 3,254,816,51 | 3,621.21 | 0.001647 | 0 |
| L | 3,254,816.52 | 3,580,297.67 | 4,157.30 | 0.0016918 | 0 |
| M | 3,580,297.68 | 3,906,090.04 | 4,707.94 | 0.0017872 | 0 |
| N | 3,906,090.05 | 11,718,268.85 | 5,290.21 | 0.0019299 | 0 |
| O | 11,718,268.86 | 24,663,843.29 | 20,366.70 | 0.0019308 | 0 |
| P | 24,663,843.30 | | 45,362.23 | 0.0020109 | 0 |

Table 2.7: Early bird percent discounts and payment deadlines

| Year | Super early bird | | Early bird | |
|---|---|---|---|---|
| | Deadline (1) | Discount (2) | Deadline (3) | Discount (4) |
| 2008 | January 31 | 7% | February 28 | 4% |
| 2009 | January 31 | 8% | February 28 | 4% |
| 2010 | January 31 | 5% | February 28 | 0% |
| 2011 | January 10 | 7% | January 31 | 3% |
| 2012 | January 17 | 7% | January 31 | 4% |
| 2013 | January 31 | 7% | February 28 | 6% |

Table 2.8: Percent discount on liability by year and value band

| Band | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| A | 0 | 0 | 0 | 0 | 0 | 0 |
| B | 0 | 0 | 0 | 0 | 0 | 0 |
| C | 0 | 0 | 0 | 0 | 0 | 0 |
| D | 0 | 0 | 0 | 0 | 0 | 0 |
| E | 65 | 65 | 65 | 65 | 65 | 50 |
| F | 45 | 45 | 45 | 45 | 45 | 35 |
| G | 30 | 30 | 30 | 30 | 30 | 20 |
| H | 20 | 20 | 20 | 20 | 0 | 0 |
| I | 15 | 15 | 15 | 0 | 0 | 0 |
| J | 10 | 10 | 0 | 0 | 0 | 0 |
| K | 0 | 0 | 0 | 0 | 0 | 0 |
| L | 0 | 0 | 0 | 0 | 0 | 0 |
| M | 0 | 0 | 0 | 0 | 0 | 0 |
| N | 0 | 0 | 0 | 0 | 0 | 0 |
| O | 0 | 0 | 0 | 0 | 0 | 0 |
| P | 0 | 0 | 0 | 0 | 0 | 0 |

**Notes:** Fiscal codes and local legislation for all years between 2008 and 2013.

Table 2.9: Summary statistics (property characteristics)

| | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Property count | 1,420,259 | 1,420,259 | 1,420,259 | 1,420,259 | 1,420,259 |
| Land area ($m^2$) | 123 | 123 | 123 | 123 | 123 |
| | (381) | (381) | (381) | (381) | (381) |
| Construction area ($m^2$) | 126 | 126 | 126 | 126 | 126 |
| | (161) | (161) | (161) | (161) | (161) |
| Year of construction | 1985 | 1985 | 1985 | 1985 | 1985 |
| | (12) | (12) | (12) | (12) | (12) |
| Property value (MXN) | 585,320 | 617,487 | 613,493 | 609,478 | 605,346 |
| | (1,121,680) | (1,185,320) | (1,180,471) | (1,174,999) | (1,169,283) |
| Yearly liability (MXN) | 1,457 | 1,540 | 1,630 | 1,704 | 1,788 |
| | (10,097) | (10,671) | (11,214) | (11,607) | (11,985) |
| Mean tax rate $\times$ 100 | .1112 | .1114 | .1198 | .1259 | .1323 |
| | (.1243) | (.1245) | (.1349) | (.1427) | (.1532) |

**Notes:** Statistics shown correspond to a balanced panel of residential properties.

Table 2.10: Summary statistics (payment characteristics)

| | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Payment (current MXN) | 1,014 | 1,007 | 1,031 | 984 | 867 |
| | (5,957) | (6,068) | (6,375) | (6,282) | (5,535) |
| Compliance share | .773 | .722 | .679 | .609 | .524 |
| | (1.007) | (.739) | (.921) | (.75) | (.713) |
| Payment type | | | | | |
| Zero payment | .201 | .221 | .272 | .332 | .414 |
| | (.401) | (.415) | (.445) | (.471) | (.493) |
| Partial payment | .092 | .108 | .114 | .095 | .083 |
| | (.289) | (.31) | (.318) | (.293) | (.276) |
| Full payment | .707 | .671 | .614 | .574 | .503 |
| | (.455) | (.47) | (.487) | (.495) | (.5) |

**Notes:** Statistics shown correspond to a balanced panel of 1,420,259 residential properties.

Table 2.11: Summary statistics on penalties, 2008-2009

| | 2008 | | 2009 | |
|---|---|---|---|---|
| | Mean | Median | Mean | Median |
| | (1) | (2) | (3) | (4) |
| Late payment dummy (before due date 2) | .086 | | .085 | |
| Inflation-adjusted liability (dummy) | .065 | | .053 | |
| Inflation-adjusted/original liability | 1.299 | 1.222 | 1.164 | 1.193 |
| Late payment (after due date 2, within 2 years) | .065 | | .053 | |
| Penalty dummy | .005 | | 0 | |
| Surcharge dummy | .065 | | .053 | |
| Seizure dummy | .001 | | 0 | |
| Penalty/Liability | .838 | 1 | .226 | .101 |
| Surcharge/Liability | .183 | .145 | .154 | .147 |
| Seizure/Liability | .019 | 0 | 0 | 0 |
| Total/Liability | 1.299 | 1.222 | 1.164 | 1.193 |
| Delinquent taxpayer dummy | .247 | | .252 | |

**Notes:** Statistics shown correspond to a bimonthly balanced panel of residential properties.

Table 2.12: Semi-parametric estimates

| | Mean tax rate | Payment amount (MXN thousands) | Payment in full (percentage points) | Compliance share × 100 |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| | *I. Estimates for the 2010 treatment* | | | |
| B | 8.726 *** | .41 *** | -3.562 *** | -1.207 *** |
| | (.183) | (.091) | (.785) | (.389) |
| Number of cadastral value bins | 34 | 34 | 34 | 34 |
| Outcome mean at baseline (treated band) | 50.112 | 5.836 | 36.626 | 47.881 |
| Implied elasticity | 1 | .404 | -.558 | -.145 |
| | | (.09) | (.123) | (.047) |
| | *II. Estimates for the 2011 treatment* | | | |
| B | 11.796 *** | .825 *** | -6.941 *** | -2.184 *** |
| | (.187) | (.129) | (.71) | (.656) |
| Number of cadastral value bins | 34 | 34 | 34 | 34 |
| Outcome mean at baseline (treated band) | 47.461 | 4.734 | 35.072 | 47.478 |
| Implied elasticity | 1 | .701 | -.796 | -.185 |
| | | (.109) | (.08) | (.056) |
| P-value ($H_0 : \varepsilon_{2011} = \varepsilon_{2010}$) | | .035 | .106 | .578 |
| | *III. Estimates for the 2012 treatment* | | | |
| B | 17.549 *** | .693 *** | -10.266 *** | -5.952 *** |
| | (.154) | (.082) | (.796) | (.478) |
| Number of cadastral value bins | 34 | 34 | 34 | 34 |
| Outcome mean at baseline (treated band) | 41.06 | 3.287 | 37.969 | 44.885 |
| Implied elasticity | 1 | .494 | -.633 | -.31 |
| | | (.058) | (.049) | (.025) |
| P-value ($H_0 : \varepsilon_{2012} = \varepsilon_{2011}$) | | .093 | .082 | .04 |
| P-value ($H_0 : \varepsilon_{2012} = \varepsilon_{2010}$) | | .4 | .576 | .002 |

**Notes:** Standard errors around the point estimate are calculated by using a bootstrap procedure in which 100 outcome change distributions are generated by random resampling of the residuals. The point estimate of B is the average difference between the observed and counterfactual outcome changes in the bins affected by the removal of the tax abatements. In 2010, the treatment band is “I”; in 2011, the treatment band is “H”; in 2012, the treatment band is “G”. The control group is composed by bands “K” and “L” in every year.

Table 2.13: Regression discontinuity estimates

| | Mean tax rate (basis points) | Payment amount (MXN thousands) | Payment in full (percentage points) | Compliance share × 100 |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| | *I. Estimates for the 2010 treatment* | | | |
| T | 11.728 *** | .935 *** | -4.419 | -2.748 |
| | (.168) | (.306) | (2.699) | (2.407) |
| Properties | 18790 | 18790 | 18790 | 18790 |
| Adjusted R-squared | .903 | .009 | .004 | .001 |
| Outcome mean at baseline (treated band) | 50.112 | 5.836 | 36.626 | 47.881 |
| Implied elasticity | 1 | .685 | -.516 | -.245 |
| | | (.224) | (.315) | (.215) |
| | *II. Estimates for the 2011 treatment* | | | |
| T | 15.681 *** | 1.055 *** | -5.554 *** | -2.293 |
| | (.236) | (.163) | (1.888) | (1.611) |
| Properties | 28993 | 28993 | 28993 | 28993 |
| Adjusted R-squared | .949 | .014 | .004 | .001 |
| Outcome mean at baseline (treated band) | 47.461 | 4.734 | 35.072 | 47.478 |
| Implied elasticity | 1 | .674 | -.479 | -.146 |
| | | (.104) | (.163) | (.103) |
| P-value ($H_0 : \varepsilon_{2011} = \varepsilon_{2010}$) | | .967 | .919 | .677 |
| | *III. Estimates for the 2012 treatment* | | | |
| T | 22.615 *** | .8050 *** | -13.204 *** | -7.943 *** |
| | (.191) | (.106) | (1.571) | (1.399) |
| Properties | 50070 | 50070 | 50070 | 50070 |
| Adjusted R-squared | .956 | .016 | .009 | .006 |
| Outcome mean at baseline (treated band) | 41.06 | 3.287 | 37.969 | 44.885 |
| Implied elasticity | 1 | .445 | -.631 | -.321 |
| | | (.058) | (.075) | (.057) |
| P-value ($H_0 : \varepsilon_{2012} = \varepsilon_{2011}$) | | .054 | .397 | .135 |
| P-value ($H_0 : \varepsilon_{2012} = \varepsilon_{2010}$) | | .3 | .721 | .732 |

**Notes:** Standard errors are robust to heterokedasticity and are clustered at the post code level. Each regression includes third-order polynomials interacted with control and treated dummies separately. The T dummy takes the value of one for properties with a cadastral value above the treatment threshold. In 2010, the treatment band is "I"; in 2011, the treatment band is "H"; in 2012, the treatment band is "G". In each year, the control group is composed by properties in the left adjacent band.

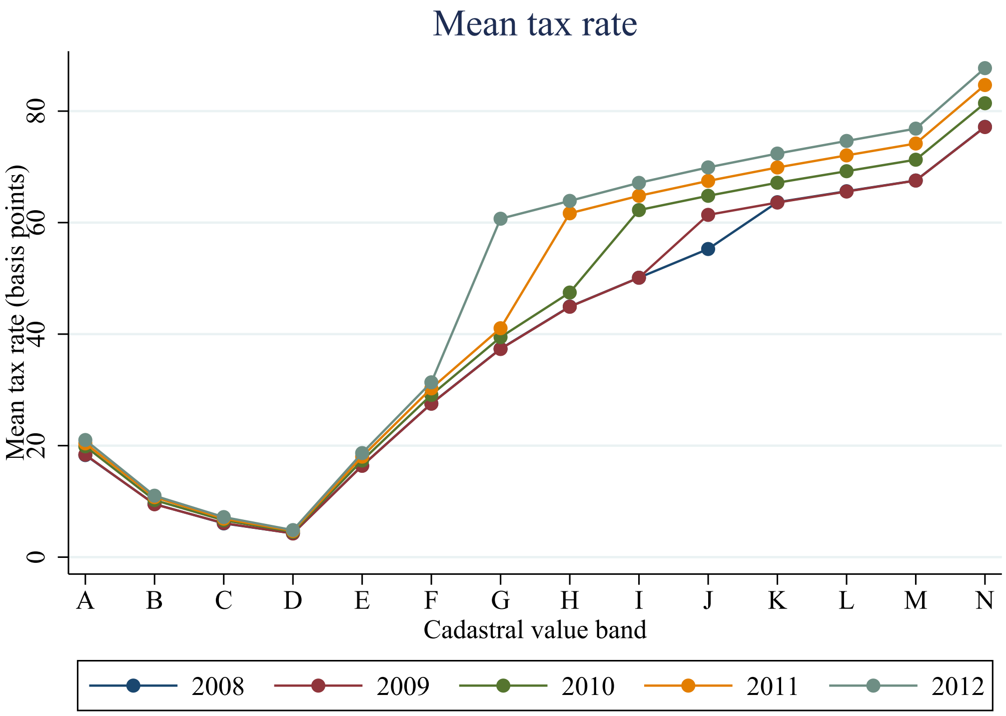
Table 2.14: Differences-in-differences estimates

| | Mean tax rate | Payment amount | Payment in full | Compliance share |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| | | *I. Estimates for the 2010 treatment* | | |
| DD | .193 *** | .134 *** | -.103 *** | -.036 *** |
| | (0) | (.013) | (.018) | (.012) |
| Adjusted R-squared | .998 | .011 | .002 | .011 |
| Properties (treatment) | 5747 | 5747 | 5747 | 5747 |
| Properties (control) | 6510 | 6510 | 6510 | 6510 |
| Implied elasticity | 1 | .6961 | -.531 | -.186 |
| | | (.067) | (.095) | (.06) |
| | | *II. Estimates for the 2011 treatment* | | |
| DD | .273 *** | .167 *** | -.152 *** | -.063 *** |
| | (0) | (.012) | (.016) | (.01) |
| Adjusted R-squared | .997 | .012 | .004 | .016 |
| Properties (treatment) | 9661 | 9661 | 9661 | 9661 |
| Properties (control) | 6511 | 6511 | 6511 | 6511 |
| Implied elasticity | 1 | .612 | -.556 | -.23 |
| | | (.044) | (.059) | (.038) |
| P-value ($H_0 : \varepsilon_{2011} = \varepsilon_{2010}$) | | .3 | .822 | .537 |
| | | *III. Estimates for the 2012 treatment* | | |
| DD | .468 *** | .156 *** | -.303 *** | -.171 *** |
| | (0) | (.013) | (.016) | (.011) |
| Adjusted R-squared | .997 | .006 | .014 | .036 |
| Properties (treatment) | 15227 | 15227 | 15227 | 15227 |
| Properties (control) | 6508 | 6508 | 6508 | 6508 |
| Implied elasticity | 1 | .333 | -.649 | -.366 |
| | | (.028) | (.035) | (.023) |
| P-value ($H_0 : \varepsilon_{2012} = \varepsilon_{2011}$) | | 0 | .174 | .002 |
| P-value ($H_0 : \varepsilon_{2012} = \varepsilon_{2010}$) | | 0 | .243 | .005 |

**Notes:** Standard errors are robust to heterokedasticity and are clustered at the property level. Each regression includes property fixed effects and time dummies. Each outcome is normalized to its mean in the pre-treatment period by group. The DD dummy is an interaction between a treatment group dummy and a dummy that takes the value of one for all periods after treatment. In 2010, the treatment band is “I”; in 2011, the treatment band is “H”; in 2012, the treatment band is “G”. The control group is composed by bands “K” and “L” in every year.

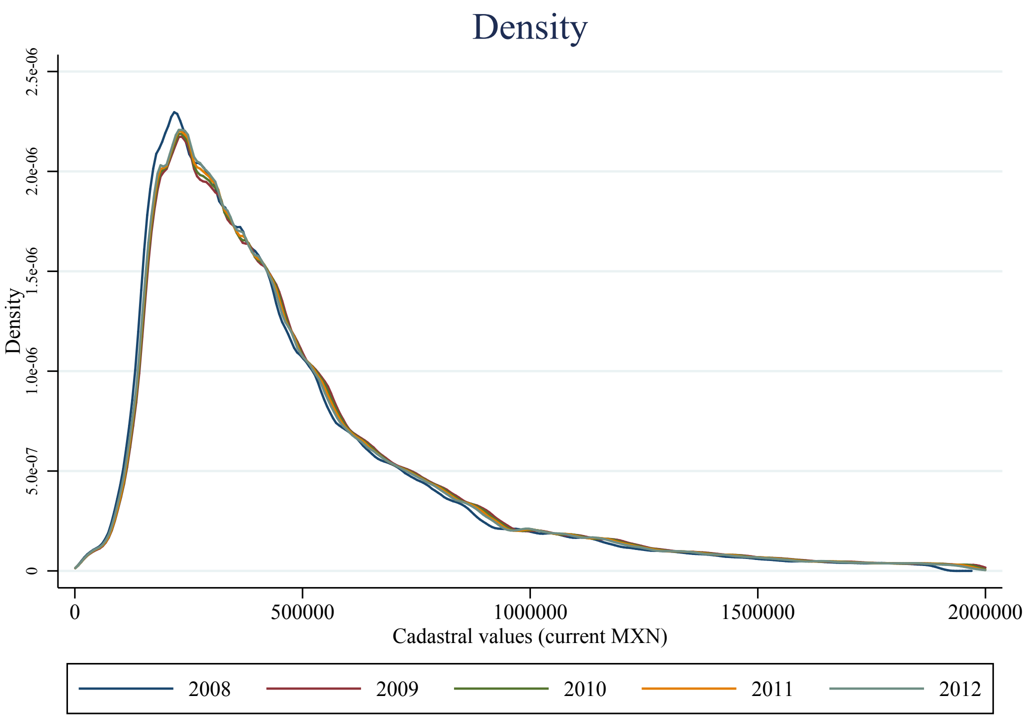
# Figures

Figure 2.1: Identifying variation in tax rates over time and across tax brackets, 2008-2012




**Note:** 100 basis points = 1 percentage point. This figure shows the average mean tax rate by cadastral value band and year.

Figure 2.2: Cadastral value distributions by year, 2008-2012




**Note:** This figures shows the cadastral value distributions by year for our balanced panel of properties.

Figure 2.3: Property tax revenues in Mexico City, 2006-2013

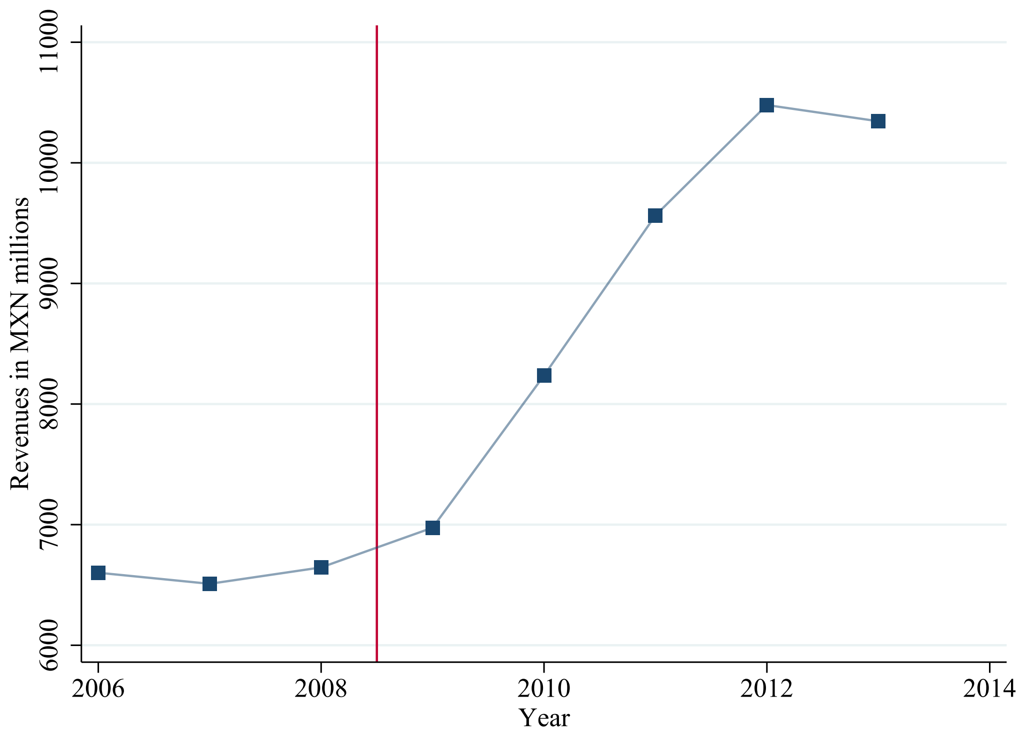
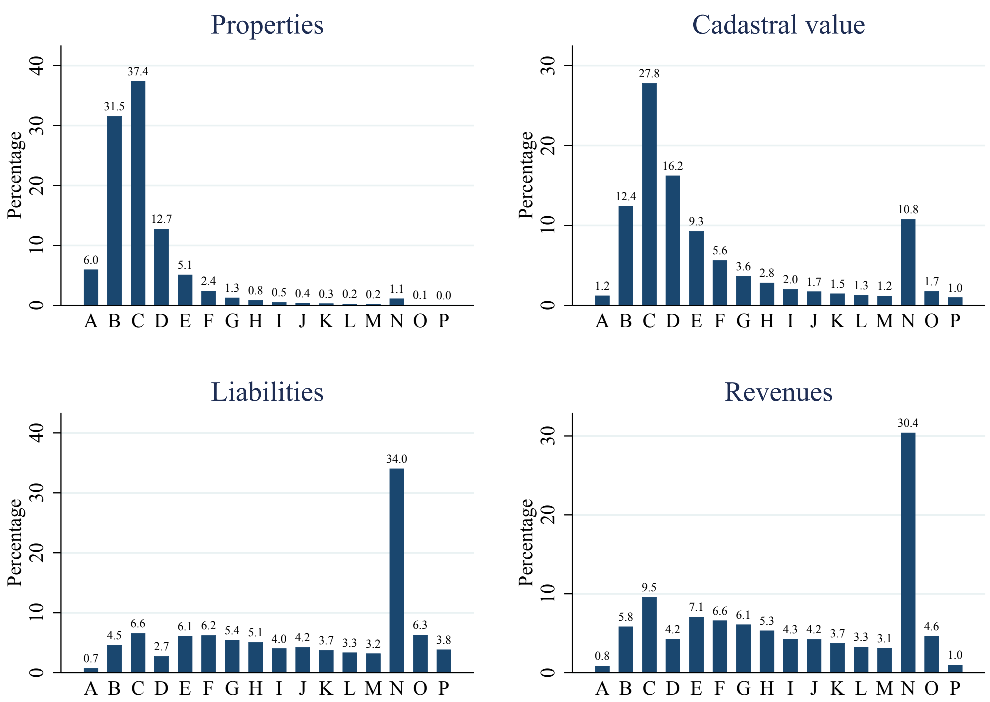
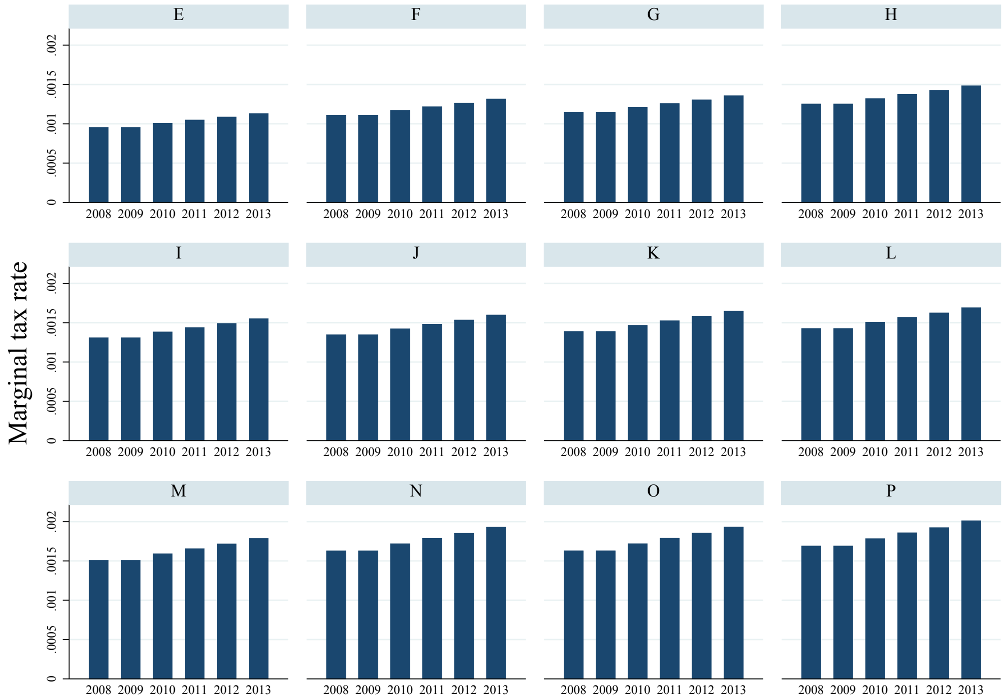



Figure 2.4: Distributions of property characteristics by value band



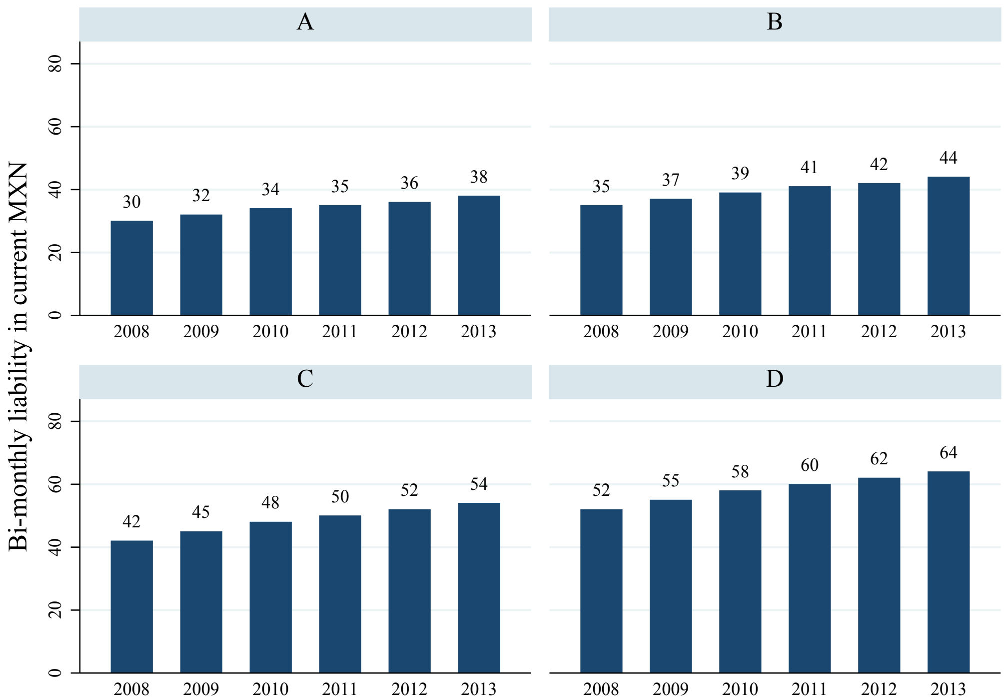

**Notes:** This figure shows the distribution of property characteristics by cadastral value band of a balanced panel of residential properties in Mexico City.

Figure 2.5: Marginal tax rates by year and cadastral value band




**Notes:** This figure shows the marginal tax rates applied to each MXN of property value in excess to the lower limit of the cadastral value band by year and.

Figure 2.6: Lump-sum liabilities by year and cadastral value band




**Notes:** The red line represents the change in the compliance share, the blue line depicts the change in the tax rate, and the green line shows the counterfactual compliance.

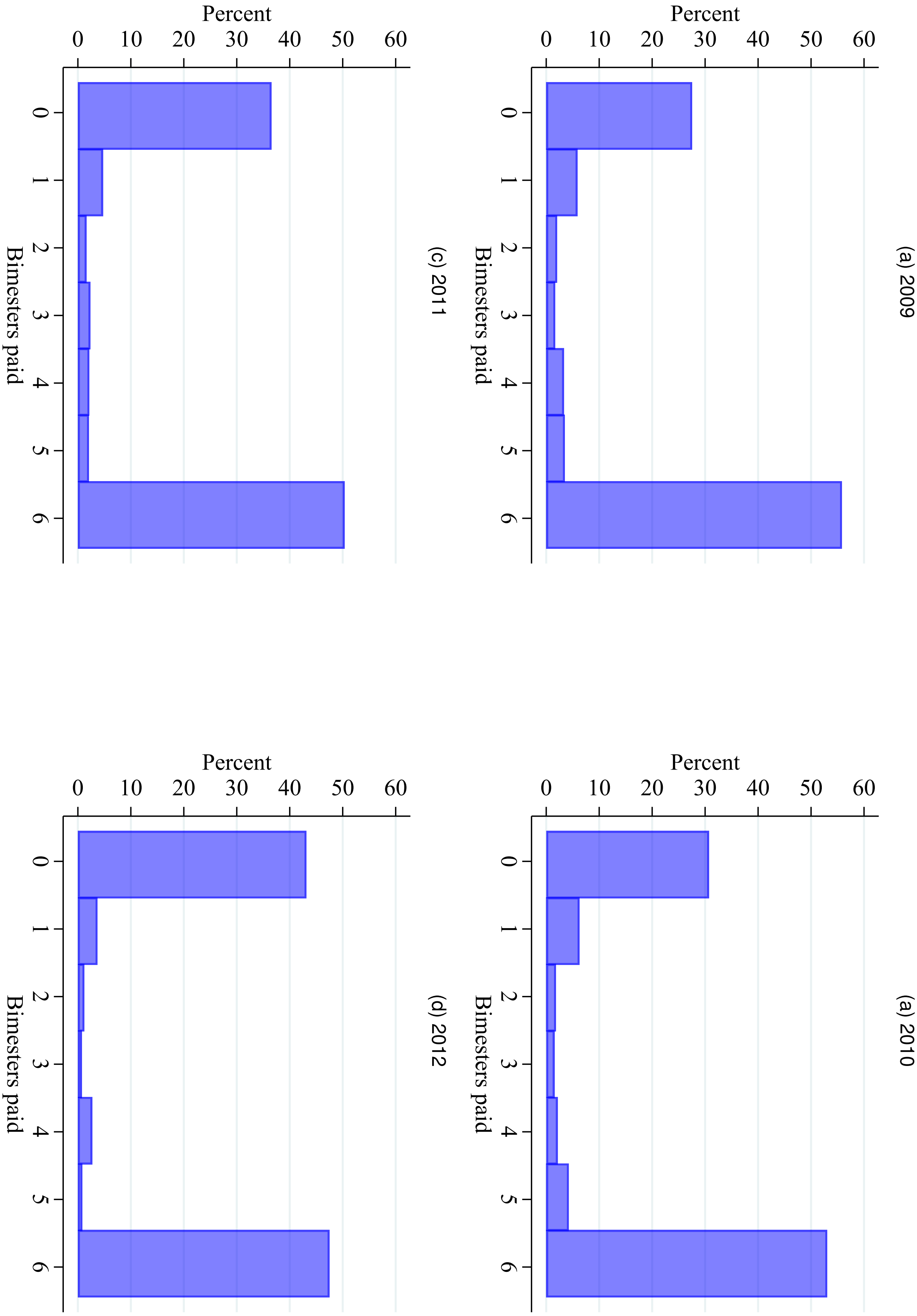
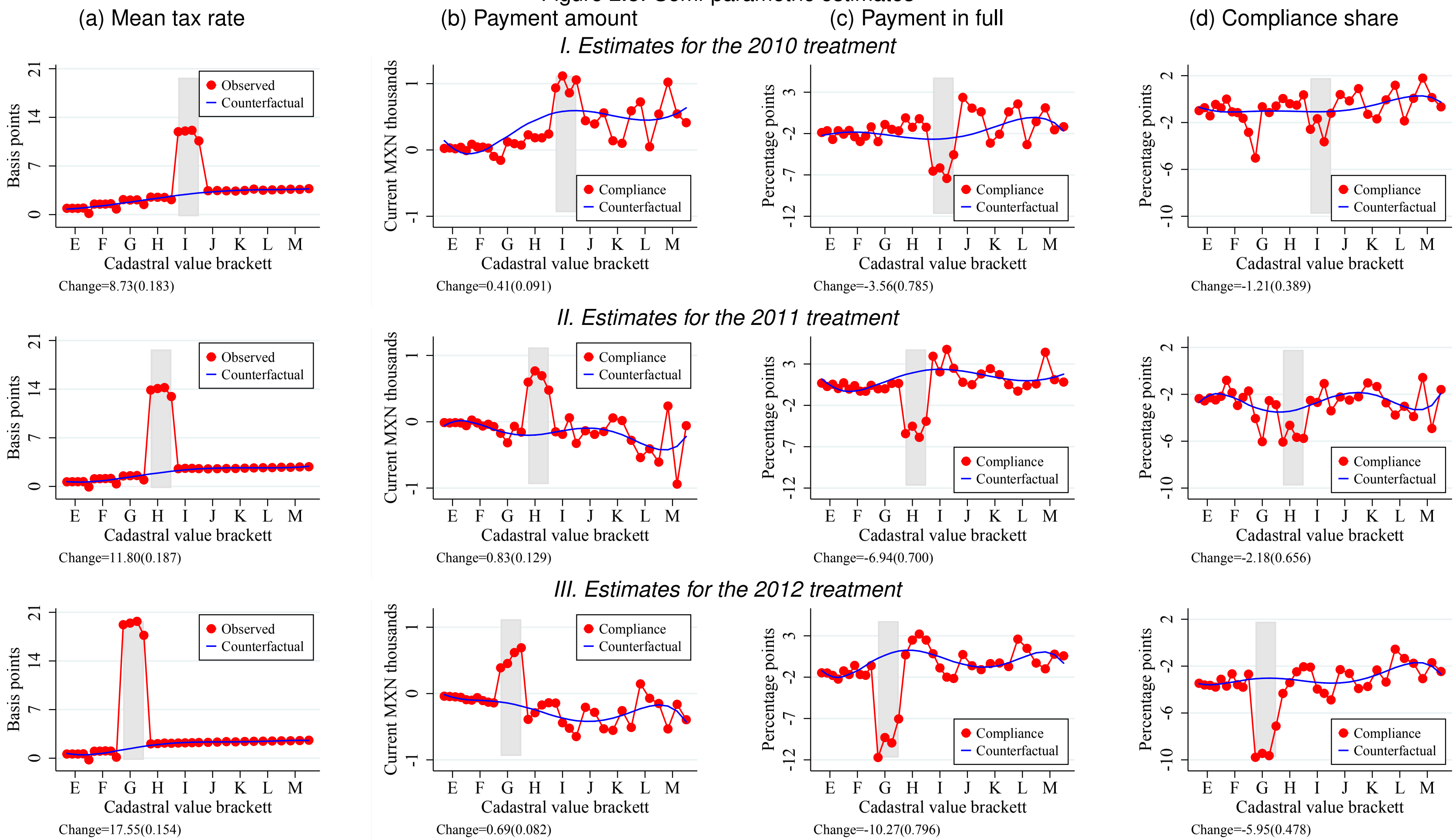


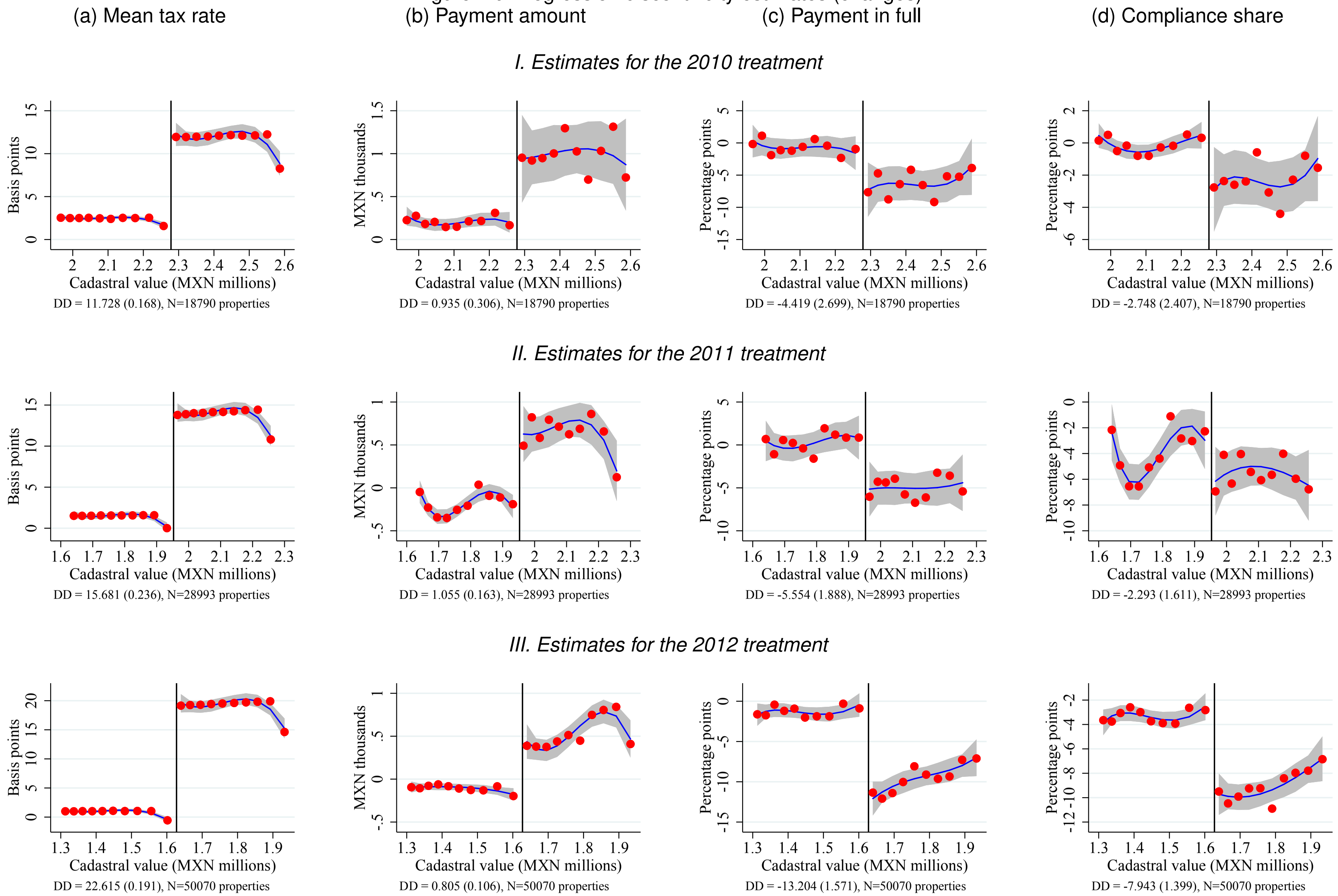

Figure 2.7: Compliance share distribution by year

Figure 2.8: Semi-parametric estimates




**Notes:** Standard errors around the point estimate are calculated by using a bootstrap procedure in which 100 outcome change distributions are generated by random resampling of the residuals. The red line in each panel represents the mean year-to-year change in the outcome of interest by cadastral value bin, and the blue line represents the counterfactual outcome distribution that would prevail under the absence of treatment. The grey area in each panel highlights the treated cadastral value band in each year. In 2010, the treatment band is "I"; in 2011, the treatment band is "H"; in 2012, the treatment band is "G".

Figure 2.9: Regression discontinuity estimates (changes)




**Notes:** The red dots in each panel represent the mean outcome within a different bin. Each panel displays 20 equally spaced bins. The solid blue lines depict a fitted third-order polynomial using control and treated units separately, while the grey areas represent the corresponding 95% confidence intervals. The vertical black lines represent the cadastral value threshold, after which the properties are treated with a tax rate increase. In 2010, the treatment band is “I”; in 2011, the treatment band is “H”; in 2012, the treatment band is “G”. In each year, the control group is composed by the left adjacent band.

Figure 2.10: Results from the McCrary test

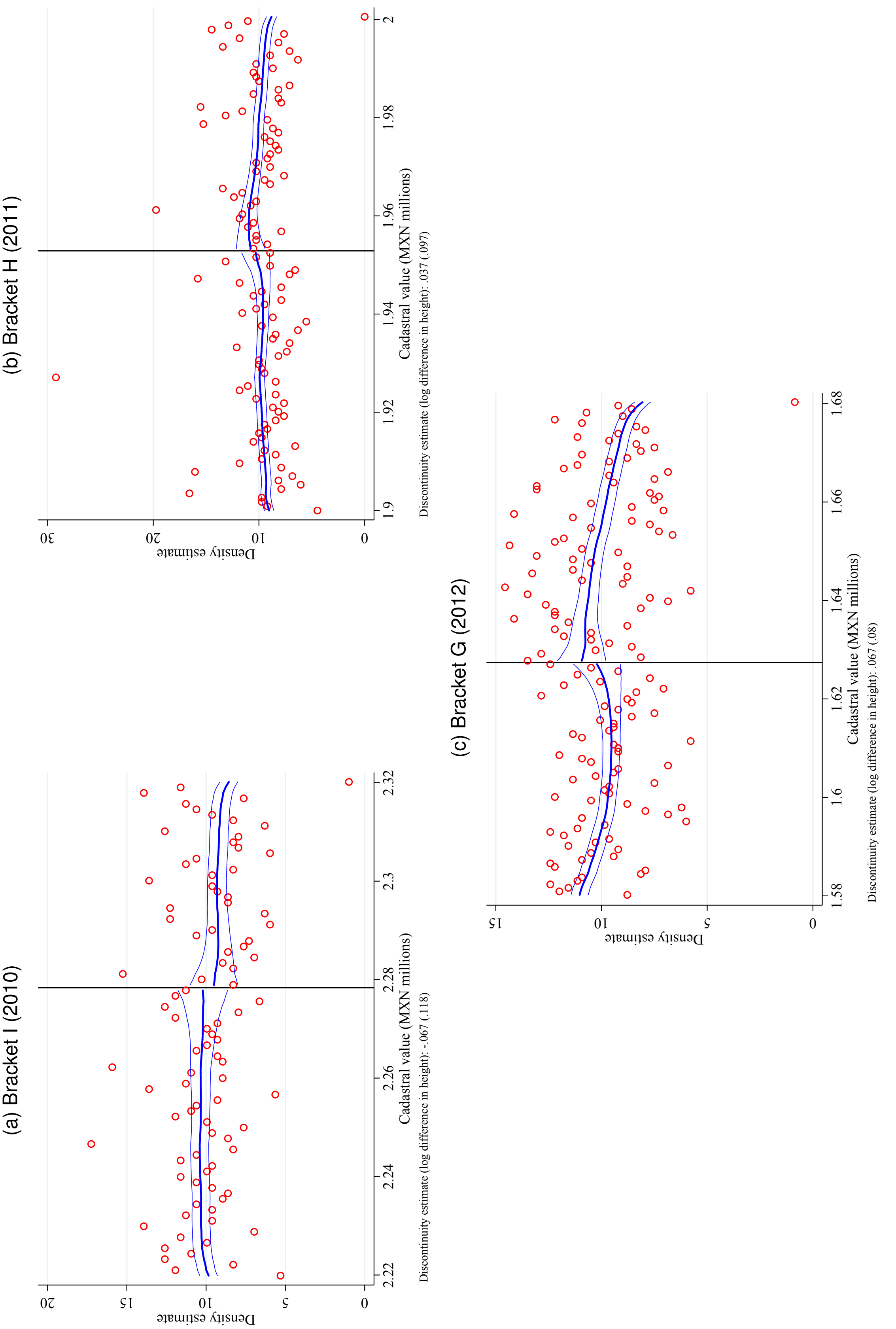
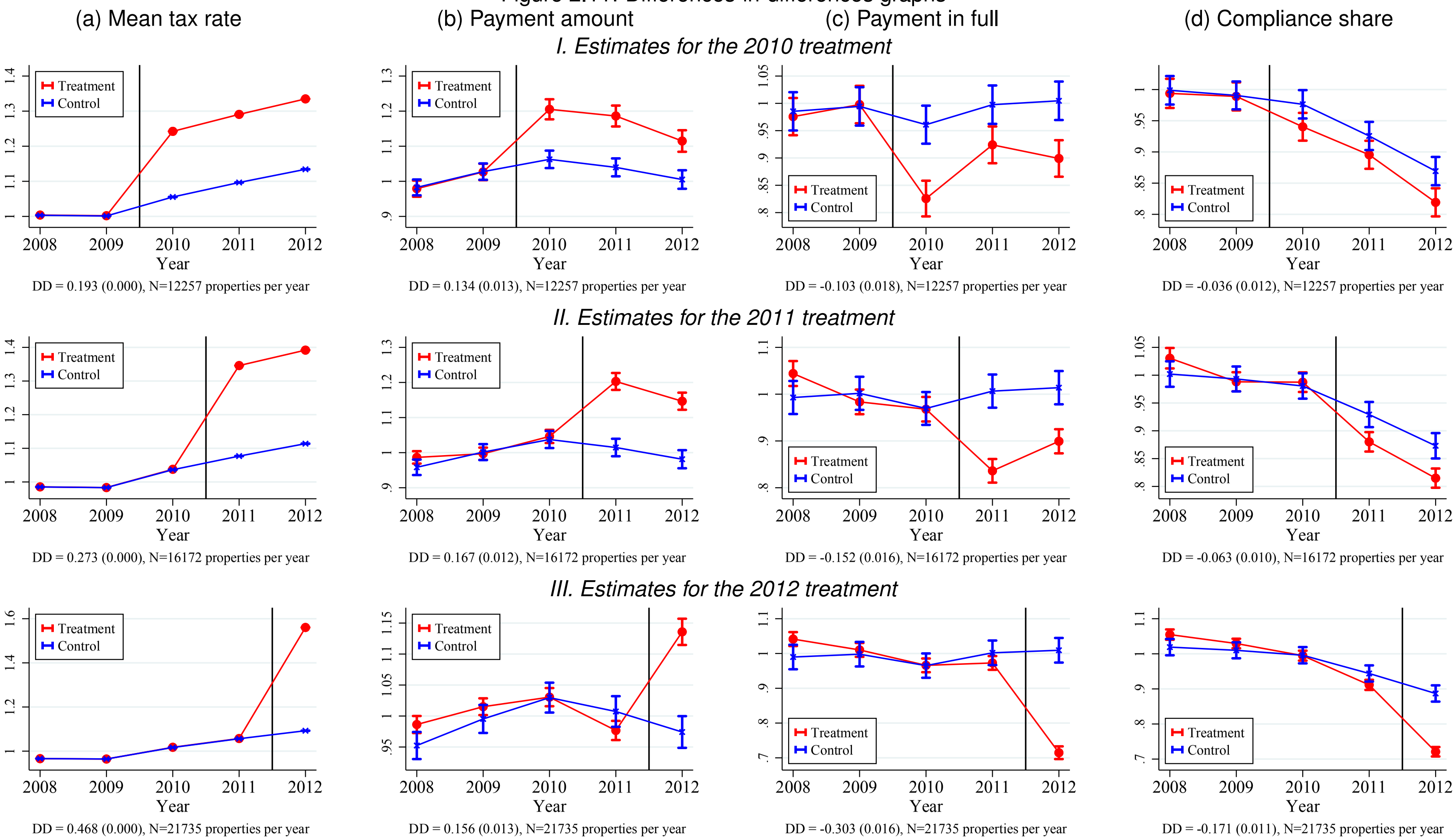


Figure 2.11: Differences-in-differences graphs




**Notes:** Standard errors are robust to heteroscedasticity and are clustered at the property level. Each panel presents the point estimates and confidence intervals from a regression of a different outcome on group dummies interacted with time dummies. Each outcome is normalized to its mean in the pre-treatment period by group. The vertical black lines represent the moment of treatment. In 2010, the treatment band is "I"; in 2011, the treatment band is "H"; in 2012, the treatment band is "G". The control group is composed by bands "K" and "L" in every year.

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# Chapter 3

# Optimal Public Investments in Schooling: A Structural Approach

*"The process of investing or disinvesting in human capital often alters the very nature of a person: training may change a life-style from one with perennial unemployment to one with stable and good earnings"* (Becker, 1993)

## 3.1 Introduction

Does generalized human capital accumulation have positive returns for the economy as a whole in the same way as human capital alters the earnings prospects of a person? The positive internal rate of return of human capital for individuals is well documented in the literature (see Heckman, Lochner and Todd, 2006), but the effects of human capital accumulation for the economy and the labour market as a whole are less clearly established (see Blundell, Dearden, Meghir and Sianesi, 1999).

This paper studies the general equilibrium effects of education on the labour market within a structural framework. The key elements of the structural model are consumers that make schooling choices before entering the labour market, a representative firm that uses different types of human capital as inputs, and a government that subsidizes education through conditional cash transfers.

Schooling decisions are modelled as individual choices that are costly to undertake but are also subsidized the government in an overlapping generations model. To evaluate the effect of government subsidies on school attendance, the paper implements the method of Aakvik, Heckman and Vytlacil (2005). This method is specially useful to analyse discrete choices in the presence of heterogeneity and selection.

Concerning the productivity of different schooling levels and the social returns of human capital accumulation in the economy, the paper estimates a nested CES production function for a representative firm that uses different types of human and physical capital as production inputs within the canonical labour supply and demand framework (Katz and Murphy, 1992).

Model estimation relies on data from Mexico between 1995 and 2015. The Mexican experience is relevant for the study of the effects of public investment in schooling on the labour market because the average years of schooling went from 7.4 in 1995 to 9.6 in 2015, partly as a consequence of the large-scale implementation of *Progresa*, an ambitious conditional-cash-transfers program studied previously in the literature (see the initial evaluation by Schultz, 2004).

Estimation of the model reveals that the productivity of individuals with middle school and high school is similar and that both are substitutes in production, whereas the productivity of the college-educated is significantly higher. The implications of this finding for the Mexican case are striking: since the improvement in schooling attainment in Mexico was the result of an increase in the number of highschool graduates, public investment resulted in wage stagnation and a reduction of the highschool wage premium.

After model estimation, the paper presents the results from a policy counterfactual simulation. In particular, the paper analyses the effects of an expansion of the existing schooling subsidies in Mexico to benefit 50 percent of the population currently not benefited by them, using the methodology of Auerbach and Kotlikoff (1987). The policy shift results in a permanent reduction of the workforce, since a larger fraction of the population is studying in every period within the simulation. However, this reduction in the workforce is eventually compensated by an increase in the effective units of labour in each period. That is, in the new steady state of the economy after the policy shift, individuals are more productive on average. In turn, the increase in average productivity implies higher steady-state levels of output, consumption, average wages, and capital rent. Wage inequality also falls, as the both the college and highschool premia fall after the policy shift. Finally, a decomposition of the effects by education level shows that the majority of these favourable results relate to an increase in the number of college graduates.

This paper contributes to the literature on the general equilibrium effects of large-scale policy shifts, which is summarized by Abbring and Heckman (2007). Previous articles that evaluate the equilibrium effects of policy shifts include Heckman, Lochner and Taber (1998*a*, 1998*b*), Blundell, Dias, Meghir and Van Reenen (2004), Duflo (2004), Lee (2005), Davidson and Woodbury (1993), Lise, Seitz and Smith (2004, 2005), and Albrecht, Van den Berg and Vroman (2005). Specific to the case of education policies in Mexico are the seminal contributions of Attanasio et al. (2012) and Todd and Wolpin (2006). Relative to these previous contributions, this paper analyses the differential effects of public investment across different schooling levels and emphasizes the role of college education in raising labour force productivity.

The remaining sections of the paper are structured as follows: section 2 presents the general equilibrium model; section 3 presents the dataset constructed to estimate the parameters of the model; section 4 presents the model estimation results; section 5 presents the policy counterfactual simulation; and section 6 concludes.

## 3.2 The model

This section describes the general equilibrium model proposed in this paper, which is similar to that of Heckman, Lochner and Taber (1998*a*). Consumer behaviour is described first, followed by a discrete choice model for schooling decisions. The role of government subsidies in influencing schooling decisions is discussed within the same subsection. Finally, the market aggregation conditions that are needed in equilibrium are described.

### 3.2.1 Consumer behaviour

This paper proposes an overlapping generations model to capture the idea that schooling decisions are affected by variables that differ across cohorts. The paper abstracts from on-the-job training heterogeneity (i.e., individuals with the same schooling level have the same wage within the model), changes in earnings related to experience or tenure, uncertainty about future earnings, and the labour supply decision.

In the model, individuals of cohort $c$ are born at period $c$ and their first period of life is $c+1$. For each of the first 6 years after they turn 12 years old, individuals choose whether to invest in education or start working, as shown by Figure 3.1. Notice from the diagram that individuals who choose to continue studying in order to complete an additional degree have no earnings for an additional 3- or 5-year period. Once an individual leaves school in the model, she cannot go back. Notice that the paper considers only schooling levels for which the individual has a role in deciding whether to attend or not: middle school, high school, and college. For each cohort $c$, individuals live for $\bar{a}$ periods.

The individual problem once in the labour market is as follows. Let $k_{at}$ denote the stock of capital held at $t$ by an individual of age $a$, and let $c_{at}$ denote the consumption at $t$ of an individual of age $a$. The rental rate of capital at $t$ is $r_t$, and the wage rate for schooling level $S$ at $t$ is $w_t^S$. As usual, denote the subjective discount factor by $\beta$. After entering the labour market, the individual maximizes the value function:

$$V(k_{at},S) = \max_{c_{at}} \left\{ \frac{c_{at}^{\gamma}-1}{\gamma} + \beta V(k_{a+1,t+1},S) \right\},$$

subject to the budget constraint:

$$c_{at} + k_{a+1,t+1} \leq r_t k_{at} + w_t^S.$$

For each cohort $c$, individuals live for $\bar{a}$ periods, so $V(k_{\bar{a}+1,t+1},S) = 0$ for all periods $t$ and education levels $S$. Above, isoelastic preferences are used with an elasticity of intertemporal substitution of $\frac{1}{1-\gamma}$.

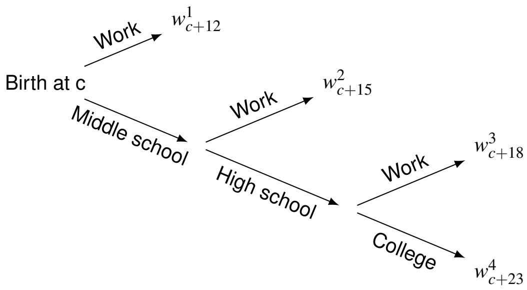



Figure 3.1: Schooling decisions

### 3.2.2 Choice of schooling level

When the individual is treated with a schooling subsidy, the lifetime utility derived from finalizing education after completing school level $S$ is given by:

$$U_{1,i}^S = V^S + X_i\beta_1^S + PE_i\gamma_1^S - c_1^S(\text{State}, LS, IRS) + u_{1,i}^S. \tag{3.1}$$

Above, $X_i$ is a vector of individual taste shifters; $PE_i$ is parental education; $c_1^S$ is a cost function, which has the state of residency, the locality size, and a local poverty index as its arguments; and $u_{1,i}^S$ are other benefits or costs of finalizing schooling at the school level $S$. For the sake of simplicity, $c_1^S$ will be assumed to be a linear function of its arguments, with a coefficient vector $\delta_1^S$. Parental education is included in the utility as means of controlling for individual ability or skills, which have been shown to be heavily correlated with parental education (Carneiro and Heckman, 2003).

Hence, the decision of attending school level $S$ when the individual $i$ is treated with a schooling subsidy is given by the following indicator:

$$A_{1,i}^S = \mathbb{1}\{\eta_1 + X_i\beta_1 + PE_i\gamma_1 - [\text{State } LS\ IRS]\delta_1 + u_{1,i} \geq 0\} \tag{3.2}$$

Above, $\eta_1 = V^S - V^{S'}$, $\beta_1 = \beta_1^S - \beta_1^{S'}$, $\gamma_1 = \gamma_1^S - \gamma_1^{S'}$, $\delta_1 = \delta_1^S - \delta_1^{S'}$, and $u_{1,i} = u_{1,i}^S - u_{1,i}^{S'}$. The superindex $S'$ denotes the education level completed before deciding whether to attend the education level $S$.

The unobserved benefits or costs from continuing schooling are assumed to follow the structure $u_{1,i} = \alpha_1\theta_i - \varepsilon_{1,i}^S$, where $\theta_i$ represents normally-distributed individual unobserved heterogeneity and

$\varepsilon_{1,i}^{S}$ represents other costs or benefits of continuing schooling, which are also assumed to be normally distributed.

On the other hand, when the individual is not treated with any schooling subsidy, the lifetime utility from finalizing schooling after completing school level $S$ is given by:

$$U_{0,i}^{S} = V^{S} + X_i\beta_0^{S} + PE_i\gamma_0^{S} - c_0^{S}(\text{State}, LS, IRS) + u_{0,i}^{S}. \tag{3.3}$$

In equation (3.3) variables have the same meaning as in equation (3.1), but the values taken by the parameters differ from those described before, since the first set of coefficients in equation (3.1) refer to the counterfactual where the individual is treated.

The decision of attending school level $S$ when the individual $i$ is not treated is given by:

$$A_{0,i}^{S} = \mathbb{1}\{\eta_0 + X_i\beta_0 + PE_i\gamma_0 - [\text{State } LS\ IRS]\delta_0 + u_{0,i} \geq 0\}. \tag{3.4}$$

Variables in equation (3.4) are the same as in equation (3.2). The only difference are the values of the coefficients that multiply them. Also, unobserved benefits or costs from schooling are assumed to follow the structure $u_{0,i} = \alpha_0\theta_i - \varepsilon_{0,i}^{S}$.

### 3.2.3 Production function

The model uses a nested CES production function with capital and 4 different types of labour as inputs:

$$F(N_t^1, N_t^2, N_t^3, N_t^4, K_t) = A\left((1-b)Q_t^{\rho_2} + bK_t^{\rho_2}\right)^{\frac{1}{\rho_2}},$$

where

$$Q_t = \left(\sum_{i=1}^{4} a_i N_t^{i\rho_1}\right)^{\frac{1}{\rho_1}},$$

and

$$\sum_{i=1}^{4} a_i = 1.$$

Above, $N_t^1$ is the number of workers with an elementary school degree or without any academic degree working at time $t$; $N_t^2$ is the number of workers at $t$ that chose in earlier periods of their life to terminate their education after completing middle school; $N_t^3$ denotes the number of workers with only a high school degree; and $N_t^4$ is the number of college-educated workers at $t$. For $i \in \{1,2,3,4\}$, the coefficient $a_i$ denotes the productivity of the $i$ type of worker. The elasticity of substitution between different types of human capital is given by $\frac{1}{1-\rho_2}$. Naturally, $K_t$ is the aggregate capital stock in the economy at $t$, $b$ is the capital share of income, and $\frac{1}{1-\rho_1}$ is the elasticity of substitution between capital and the "effective" units of labour in the economy, $Q_t$. Finally, $A$ is the total productivity of the factors.

Notice that this is a constant returns to scale production function, so under perfect competition the rental rate of each factor is equal to its marginal productivity.

### 3.2.4 Aggregation conditions

Let $N^S_{c,t}$ be the number of persons of cohort $c$ with schooling level $S$ in the labour market at time period $t$. The total number of people with schooling level $S$ working in the economy at $t$ is therefore given by:

$$N^S_t = \sum_{c=t-\bar{a}}^{t-S} N^S_{c,t}.$$

Let $K^S_{c,t}$ be the capital stock held by individuals of cohort $c$ with schooling level $S$ at time period $t$. The aggregate capital stock at $t$ is given by:

$$K_t = \sum_{S=1}^{4} \sum_{c=t-\bar{a}}^{t-S} K^S_{c,t}.$$

In equilibrium, output at $t$ is equal to aggregate consumption plus investment by Walras' law.

### 3.2.5 The government

In the model, the government subsidizes education by giving cash transfers to selected individuals conditional on school attendance. Selection of beneficiaries is determined using a three-stage procedure. First, the government uses data from a representative survey to regress individual income, $y$, on a set of characteristics of the individual, $Z$, which are selected for their explanatory power. Specifically, the government estimates the following equation via OLS:

$$y = Z\beta + u. \tag{3.5}$$

Second, a socio-economic study is applied to all individuals in the economy below an age cut-off by collecting all their $Z$ data. An individual is eligible for treatment if her predicted income, $\hat{y} = Z\hat{\beta}$, is below a subsistence threshold, which aims to reflect the inability of the individual to invest appropriately in education, healthcare, and nutrition.

Third, the government makes a final decision concerning whether to treat an individual by pooling data on the outcome of her socio-economic study and other sensible information. Specifically, the decision of the government is favourable for the individual if the latent variable in the following selection equation is greater than or equal to zero:

$$T_i^* = [SE_i \; X_i \; \text{Rural}_i \; IRS]\Pi^S + \zeta^S_{\text{State}} + \mu_i^S. \tag{3.6}$$

Above, $SE_i$ is a dummy for the event in which the socio-economic study prescribes eligibility of individual $i$; $X_i$ is a vector of characteristics of individual $i$ that are sensible for the government official when deciding whether to select individual $i$ as beneficiary; Rural$_i$ indicates that individual $i$'s the locality of residence is rural; IRS is the value of a poverty index at the locality of residence of the individual; $\zeta^S_{\text{State}}$ is a state effect, which is aimed at capturing differences in preferences of the government officials across states; and $\mu_i^S$ are other determinants of the selection decision, which are assumed to be a combination of individual unobserved heterogeneity and other normally distributed determinants, or $\mu_i^S = \theta_i + u_{Di}$.

The selection decision of the government can then be described by:

$$T_i = \mathbb{1}\{T_i^* \geq 0\}. \tag{3.7}$$

The mechanism through which the socio-economic study is used to determine eligibility is unknown to households, but its prescription should be correlated with treatment. This will prove useful for estimation purposes in the next section of the paper, since selection to the program as prescribed by the socio-economic study will satisfy the exclusion and relevance restrictions that are required to obtain consistent estimates of the treatment effects of interest (see Aakvik, Heckman and Vytlacil, 2005).

## 3.3 Data

This section summarizes the data sources for estimation of the structural model. The paper begins by describing the data source for wages and labour supply by skill level, used in subsequent sections to estimate the production function of the representative firm in the economy. Next, the paper turns to describing the data source for individual schooling choices. Finally, additional data sources are described.

### 3.3.1 Wages and labour supply

This paper uses data from labour force survey, or *Encuesta Nacional de Ocupación y Empleo* (ENOE), the longest high-frequency survey of Mexican local labour markets.[1] This survey, which is levied on a quarterly basis, collects individual information from both rural and urban areas and is representative at the municipality level. The ENOE is a rotative panel survey that follows a nationally representative sample of households. Each household is followed for 5 quarters, and one fifth of the sample is replaced by a new set of households each quarter. Micro-data from this survey is used to construct measures of labour supply and hours worked, as well hourly wages and monthly real earnings by skill level. The paper applies the ENOE's sampling weights for all calculations. Table 3.1 shows the demographic characteristics of the Mexican workforce between 1995 and 2015.

### 3.3.2 Choice of schooling level

This paper uses micro-data on school choices of 2.9 million households from the amplified questionnaire of the latest population census, the *Censo Nacional de Población y Vivienda*, which was conducted by national institute of statistics between May and June of 2010. In addition to surveying data on gender, age, literacy, school attendance, and school attainment of all members of the household, the amplified version of the census survey collects data on the cash transfers made by the government to the household. To determine whether an individual is recipient of some social program, the paper uses the answer to the following item of the amplified questionnaire: "Do you receive money from any social program implemented by the government (Progresa-Oportunidades, Procampo, scholarships, help to single mothers and the elderly, etc)?".

### 3.3.3 Additional sources of data

**Number of classrooms**

In the following section, the paper uses the number of classrooms for each education level in each municipality as an instrument for the relative supply of human capital. To this end, the paper uses administrative dataset of all the schools in Mexico, both private and public, for all education levels and modalities. Information in the dataset corresponds to the 2014-2015 academic year and includes location and number of teachers, students, and classrooms for each school of the country. Table 3.2 provides summary statistics of the dataset.

[1] The survey sampling frame and methodology improved significantly in 2005, year in which the name of the survey changed from *Encuesta Nacional de Empleo* (ENE) to its current name.

#### Capital stock

Finally, estimation of the production function requires data on the capital stock at the national level. The paper uses data from the latest economic census, the *Censos Económicos 2014*, levied by INEGI between February and July of 2014. The census encompasses data on 981 activities and data on 5.6 million firms, excluding agriculture and cattle raising activities. As a measure of physical capital, this paper uses the total value of the fixed assets at the municipal level. Fixed assets are defined as goods with a useful life greater than a year that provide services or have the potential of generating either goods or services.

## 3.4 Model estimation

This section describes the estimation strategy used to recover the parameters of the structural model. Exposition begins in the first subsection by describing estimation of the school choice model. The same subsection describes the methodology used to recover the effect of government subsidies over schooling decisions. Next, the second subsection describes the estimation method for the production function of the economy. Finally, the last subsection describes how the rest of the parameters of the model were calibrated.

### 3.4.1 School choice

#### Methodology

This paper uses Maximum Likelihood Estimation (MLE) to estimate a discrete choice model of school decisions. In addition, to evaluate the effect of *Progresa* and other schooling subsidies over individual decisions, the paper follows the methodology of Aakvik, Heckman and Vytlacil (2005), which allows the for selection and heterogeneity in treatment effects.

Let $A_i^S$ be an indicator of attendance to school level $S$ after completing the preceding education level, let $A_{1i}^S$ denote the potential attendance decision for the same school level $S$ if school subsidies were exogenously assigned to individual $i$, and let $A_{0i}^S$ denote the potential outcome in the absence of schooling subsidies. Then,

$$A_i^S = \begin{cases} A_{1i}^S \text{ if } T_i = 1 \\ A_{0i}^S \text{ if } T_i = 0. \end{cases}$$

After conditioning on $\theta$, the likelihood of being selected to be a beneficiary of *Progresa* or any other schooling subsidy and continue schooling after completing education level $S$ for a sample of $N^S$ individuals is given by:

$$\prod_{i=1}^{N^S} \text{Pr}(T_i, A_i^S | \theta_i, X_i, Z_i),$$

where

$$\text{Pr}(T_i, A_i^S | \theta_i, X_i, Z_i) = \text{Pr}(T_i | \theta_i, X_i, Z_i) \text{Pr}(A_i^S | \theta_i, X_i, Z_i, T_i),$$

$$\text{Pr}(T_i = 1 | \theta_i, X_i, Z_i) = \Phi(Z_i \beta_D + \theta_i),$$

$$\text{Pr}(A_i^S | \theta_i, X_i, Z_i, T_i = 1) = \text{Pr}(A_{1i}^S = 1 | \theta_i, X_i)^{A_i^S} (1 - \text{Pr}(A_{1i}^S = 1 | \theta_i, X_i))^{1 - A_i^S},$$

$$\text{Pr}(A_{1i}^S = 1|\theta_i, X_i) = \Phi(X_i\beta_1 + \alpha_1\theta_i),$$

$$\text{Pr}(A_i^S|\theta_i, X_i, Z_i, T_i = 0) = \text{Pr}(A_{0i}^S = 1|\theta_i, X_i)^{A_i^S}(1 - \text{Pr}(A_{0i}^S = 1|\theta_i, X_i))^{1-A_i^S},$$

and

$$\text{Pr}(A_{0i}^S = 1|\theta_i, X_i) = \Phi(X_i\beta_0 + \alpha_0\theta_i).$$

Hence, under the assumption that $\theta \perp\!\!\!\perp (X, Z)$, the log-likelihood for the data is given by:

$$\int \left( \log \prod_{S=2}^{4} \prod_{i=1}^{N^S} \text{Pr}(T_i, A_i^S|\theta_i, X_i, Z_i) \right) \phi(\theta_i) d\theta_i = \sum_{S=2}^{4} \sum_{i=1}^{N^S} \log \left( \int \text{Pr}(T_i, A_i^S|\theta_i, X_i, Z_i) \phi(\theta_i) d\theta_i \right).$$

This likelihood is maximized using numerical integration and optimization.

In the derivation of the log likelihood function this paper makes use of the joint normality assumption $(\varepsilon_1\ \varepsilon_0\ \varepsilon_D\ \theta) \sim N(O, \mathbb{I})$. The most important advantage of specifying a particular distribution for the unobserved variables in the model is that the following analytical expressions for the mean treatment parameters of the schooling subsidies can be verified:

$$\text{ATE}(X_i) = \int [\Phi(X_i\beta_1 + \alpha_1\theta_i) - \Phi(X_i\beta_0 + \alpha_0\theta_i)]\, \phi(\theta_i)\theta_i,$$

$$\text{TT}(X_i, Z_i) = \frac{1}{\Phi(\frac{Z_i\beta_D}{\sqrt{2}})} \int [\Phi(X_i\beta_1 + \alpha_1\theta_i) - \Phi(X_i\beta_0 + \alpha_0\theta_i)]\, \Phi(Z_i\beta_D + \theta_i)\phi(\theta_i) d\theta_i,$$

and

$$\text{MTE}(X_i, Z_i\beta_D = u) = \frac{1}{\phi(\frac{u}{\sqrt{2}})} \int [\Phi(X_i\beta_1 + \alpha_1\theta_i) - \Phi(X_i\beta_0 + \alpha_0\theta_i)]\, \phi(u + \theta_i)\phi(\theta_i) d\theta_i.$$

The following expressions for the distributional treatment parameters can also be derived:

$$E[\Delta = 1|X_i] = \int \Phi(X_i\beta_1 + \alpha_1\theta_i)(1 - \Phi(X_0\beta_0 + \alpha_0\theta_i))\phi(\theta_i) d\theta_i,$$

$$E[\Delta = 1|X_i, D = 1] = \frac{1}{\Phi(\frac{Z_i\beta_D}{\sqrt{2}})} \int \Phi(X_i\beta_1 + \alpha_1\theta_i)(1 - \Phi(X_i\beta_0 + \alpha_0\theta_i))\Phi(Z_i\beta_D + \theta_i)\phi(\theta_i) d\theta_i,$$

$$E[\Delta = 1|X_i, Z_i\beta_D = u] = \frac{1}{\phi(\frac{u}{\sqrt{2}})} \int \Phi(X_i\beta_1 + \alpha_1\theta_i)(1 - \Phi(X_i\beta_0 + \alpha_0\theta_i))\phi(u + \theta_i)\phi(\theta_i) d\theta_i,$$

$$E[\Delta = -1|X_i] = \int (1 - \Phi(X_i\beta_1 + \alpha_1\theta_i))\Phi(X_0\beta_0 + \alpha_0\theta_i)\phi(\theta_i) d\theta_i,$$

$$E[\Delta = -1|X_i, D = 1] = \frac{1}{\Phi(\frac{Z_i\beta_D}{\sqrt{2}})} \int (1 - \Phi(X_i\beta_1 + \alpha_1\theta_i))\Phi(X_i\beta_0 + \alpha_0\theta_i)\Phi(Z_i\beta_D + \theta_i)\phi(\theta_i) d\theta_i,$$

and

$$E[\Delta = -1|X_i, Z_i\beta_D = u] = \frac{1}{\phi(\frac{u}{\sqrt{2}})} \int (1 - \Phi(X_i\beta_1 + \alpha_1\theta_i))\Phi(X_i\beta_0 + \alpha_0\theta_i)\phi(u + \theta_i)\phi(\theta_i)d\theta_i.$$

The distribution of the unobservables is also useful for computing the so-called average marginal effects:

$$E_X\left[\frac{\partial E[\Delta|X=x]}{\partial x_k}\right] = \int \frac{\partial E[\Delta|X=x]}{\partial x_k} dF_X,$$

and

$$E_X\left[\frac{\partial E[\Delta|X=x]}{\partial x_k}\middle| D=1\right] = \int \frac{\partial E[\Delta|X=x]}{\partial x_k} dF_{x|D=1}.$$

**Results**

**Selection to treatment** Table 3.3 shows the estimates of the selection equation for *Progresa* and other government subsidies separately for middle school, high school, and college education. Almost all coefficients in the 3 selection equations are significant at the 1 percent, except for the gender and rural locality coefficients in the middle school equation and the indigenous coefficient in the college selection equation, which are significant at the 10 percent level. The outcome of the socio-economic study is the variable that increases the probability of being treated by *Progresa* or other subsidies the most: 12.2 percent for middleschool, 10.8 percent for highschool, and 6.6 percent for college. The second variable in importance is the locality poverty index, which implies a 10.5 percent increase in the probability of being treated in middle school, an 8.1 percent increase in highschool, and a 4 percent increase for college. Individuals living in rural localities are less likely to be selected for treatment, an observation that becomes more pronounced for higher education levels: living in a rural locality implies a 0.6 decrease in the probability of being treated in middle school, while the same variable implies a 3.1 decrease in the probability of being treated in highschool and a 2 percent decrease in the probability of being treated in college. Indigenous individuals are more likely to be treated, as the indigenous dummy coefficient implies a 4.7 percent increase in the probability of being treated at middleschool, a 3.4 percent increase at highschool, and a 1.1 percent increase at college.

**Unobserved heterogeneity** Table 3.4 shows the individual unobserved heterogeneity coefficients for the attendance equations for middleschool, highschool, and college education. Under the no-treatment state, unobserved heterogeneity is positively correlated with middleschool and highschool attendance, while being negatively correlated with college attendance. In contrast, under the treatment state, unobserved heterogeneity is negatively correlated with middleschool and highschool attendance, while being positively correlated with college attendance. In other words, treatment makes individuals with high levels of unobserved heterogeneity less likely to terminate education during middleschool or highschool, while making them more likely to attend college.

**Attendance equations** Table 3.5 shows the coefficients for observable characteristics in the attendance equations for middleschool, highschool, and college education. The female dummy coefficients reveal that females are more likely to attend school under the treatment state for all education levels, as the marginal effects of the female dummy are higher in the treatment state than in the no-treatment state for all education levels. Similarly, individuals living in poor localities become more likely to attend school under the treatment state for all education levels. Marginal effects estimates also reveal that indigenous individuals are more likely to attend school under the treatment state for highschool and college, although they are equally likely to attend middleschool under treatment and no-treatment. Higher parental education is unambiguously correlated to school attendance for all education levels in the no treatment state, but this relationship between parental education and school attendance is weakened by treatment. With respect to locality size, all coefficients are positive in the no-treatment state for all education levels, indicating that individuals living at non-rural localities are more likely to attend school for all education levels in the absence of subsidies. The coefficients of locality size in the treatment state, however, indicate that this relationship is substantially weakened by education subsidies.

**Average Treatment Effects** The Average Treatment Effect (ATE) of *Progresa* and other educational subsidies are shown in Table 3.6. This table reports a 5.2 percent increase in the probability of attending middleschool, a 26 percent increase in the probability of attending highschool, and a 30 percent increase for college attendance. The distributional version of the ATE is also shown in the table: the probability that the treatment results in a favourable change in the school attendance decision is 5.8 percent for middleschool, 27.1 percent for highschool, and 44.8 percent for college. The probability that the treatment results in no change in the attendance decision is 93.7 percent in middleschool, 71.9 percent in highschool, and 41.2 percent in college. Furthermore, the probability that treatment results in an unfavourable change in the attendance decision is 0.5 percent for middleschool, 1.1 percent for highschool, and 14 percent for college.

Figure 3.2 deepens the understanding of the distributional version of the ATE. The top row shows information for middleschool, the second row shows information for highschool, and the bottom row shows information for college. The 3 panels in the left of the figure plot the probability that treatment results in a favourable change of the attendance decision against the indexes that determine the attendance decision under the treatment and no-treatment states, $X\beta_1$ and $X\beta_0$. Clearly, the probability that treatment results in a favourable change in the attendance decision is higher for individuals that would decide not to attend in the no-treatment state. On the other hand, the panels in the middle column show the probability that treatment does not change the attendance decision against $X\beta_1$ and $X\beta_0$. These middle panels indicate that individuals who are already prone to attend in the no-treatment state are unlikely to reverse their decision as a consequence of treatment. Finally, the panels in the right of the figure plot the probability that treatment results in an unfavourable change in the attendance decision against $X\beta_1$ and $X\beta_0$. These last panels reveal that the probability of changing unfavourably the attendance decision after treatment is higher only for a set of individuals who are deterred from attending as a consequence of educational subsidies.

**Average Treatment Effects on the Treated** Table 3.6 above also provides estimates of the Average Treatment Effect on the Treated (TT) for different schooling levels, as well as the distributional version of the of this treatment parameter. The middleschool point estimate of the TT indicates that Mexican social policy programs have no effect on attendance decisions of the treated population. On the other hand, the effect of these programs on highschool attendance is a 4.6 percent increase in the probability of attendance on average for the treated population, and the effect for college attendance is a 79 percent increase in the attendance probability.

**Marginal Treatment Effects** Furthermore, Table 3.6 provides estimates of the Marginal Treatment Effect (MTE) and of its distributional version for the 3 education levels under consideration. The MTE estimates are provided for 3 different levels of the selection index, $Z\beta_D$. For high positive levels of this index, the MTE corresponds to individuals with unobserved characteristics that make them least likely to be selected into *Progresa* and other transfers, whereas for low levels of the selection index the MTE corresponds to individuals with unobserved characteristics that make them more likely to be selected into treatment. Examination of the estimates in the table demonstrates that the MTE increases with the selection index for middleschool and highschool, implying that treatment would be more effective in inducing attendance for those individuals who are currently unlikely to be selected for treatment based on their unobservable characteristics. An opposite observation holds for the college MTE: treatment is more effective in inducing attendance for individuals who are more likely to be selected into treatment based on their unobservable characteristics.

To build intuition, Figure 3.3 provides a graph of the MTE against the value of the selection index, $Z\beta_D$, for all education levels under consideration. The MTE is increasing with the selection index for both middleschool and highschool, but is decreasing for college. Moreover, the magnitude of the middleschool MTE estimate is less than 10 percent for all values of the index, whereas the MTE is around 30 percent for highschool and college. This suggests that, even for indifferent individuals, treatment is more effective in changing the attendance decisions for highschool and college than for middleschool. Point estimates are estimated imprecisely, however, as revealed by the wide confidence intervals in the figure.

**Average Marginal Effects** Table 3.7 contains the average marginal effects and the average marginal effects on the treated for the 3 education levels under consideration, conditional on the following variables: gender, an indigenous dummy, the locality poverty index (IRS), and parental education. The average marginal effect is a decreasing function of parental education, implying that the treatment effect decreases as parental education increases. That is, individuals coming from educated families are less likely to be affected in their attendance decision by the *Progresa* or other transfers than individuals whose parents have less education. Estimates in the table also imply that the average marginal effect is higher for individuals living in poor localities and that the average marginal effect on the treated increases for individuals living in poor localities for middleschool and highschool, but not for college. Similarly, the average marginal effect on the treated is higher for indigenous individuals for all education levels, whereas the average marginal effect increases for indigenous individuals at highschool and college, but not for individuals at middleschool. Estimates of the marginal effects conditional on gender are close to zero for all education levels.

Finally, Table 3.8 examines the correlation between the determinants of treatment and the those of school attendance. In particular, the table measures the correlation between $Z\beta_D$ and $X(\beta_1-\beta_0)$, as well as the correlation between $U_D$ and $U_1-U_0$. Other important correlations are: the correlation between the latent variables $D^*$ and $Y_1^*-Y_0^*$, and the correlation between the probability that treatment changes the attendance decision conditional on observable variables, $\Pr(D=1|Z)$, and the average treatment effect conditional on observable variables, $E[\Delta|X]$. Examination of the correlations of interest reveals that the probability of being selected conditional on observable variables is highly correlated to the probability of changing favourably the attendance decision conditional on the observable individual variables for all education levels. Also, the correlation between the observable determinants of treatment and attendance is high for middle school and college, but not for highschool, implying that the government adequately selects beneficiaries for the former education levels, but not for the latter.

### 3.4.2 Production function

#### Methodology

Taking the log of the ratio of the first order condition of the problem of the firm with respect to education level $i \in \{1,2,3\}$ to the first order condition of the firm with respect to the consecutive education level $i+1$ yields the following relation:

$$\log\left(\frac{w_t^i}{w_t^{i+1}}\right)=\log\left(\frac{a_i}{a_{i+1}}\right)+(\rho_1-1)\log\left(\frac{N_t^i}{N_t^{i+1}}\right)+\upsilon_t.$$

Above, $\upsilon_t$ represents a mean-zero deviation from the equality implied by the ratio of the first order conditions. Notice that the total productivity of the factors has been differenced out when taking ratios. GMM estimation yields consistent estimates of the parameters of interest (i.e., the parameters $\rho_1$ and $a_i$ for $i \in \{1,2,3,4\}$) under the identifying assumption that the ratios of different types of labour supply are uncorrelated with unobserved correlates of relative earnings other than total factor productivity.

Once estimated the parameters of the production function related to labour, the paper uses this information to estimate the number of "effective" units of labour, $Q_t$, and the hourly earnings per "effective" unit of labour, $w_t^Q$. In turn, the estimated variables $Q_t$ and $w_t^Q$ are used to estimate the parameters of the production function related to capital by the taking log of the ratio of the first order condition of the firm with respect to $Q_t$ to the first order condition of the capital stock:

$$\log\left(\frac{w_t^Q}{r_t}\right) = \log\left(\frac{1-b}{b}\right) + (\rho_2 - 1)\log\left(\frac{Q_t}{K_t}\right) + \omega_t.$$

Once again, $\omega_t$ is a mean-zero deviation from the equality implied by the ratios of the first order conditions with respect to $Q_t$ and $K_t$. GMM yields consistent estimates of the parameters $b$ and $\rho_2$ under the assumption that the ratio of "effective" units of labour to the capital stock is uncorrelated with unobserved correlates of relative prices other than the total factor productivity.

#### Results

To estimate these equations, the paper uses data on the number of workers and their average wages for each education level at the municipal level for the 287 most populated municipalities out of 2,457 municipalities in Mexico, contained in the national survey of employment. The results from two-stage GMM estimation are shown in Column (1) of Table 3.9. Productivity levels for different types of workers are estimated precisely, with the productivity of the college-educated individuals almost doubling the productivity of the other types of workers. Specifically, the productivity of workers without a degree or with completed elementary education is estimated at 0.186 at the 5 percent significance level; the middleschool degree productivity estimate is 0.202, significant at the 10 percent; for workers with a highschool degree, productivity is estimated at 0.227 at the 1 percent significance level; and the estimate of the productivity of the college educated is 0.385, significant at the 5 percent. The rest of the parameters are estimated imprecisely, as standard errors are corrected for two-stage estimation as in Newey and McFadden (1994): $\rho_1$ is estimated at 0.913, a value slightly higher than the value estimated by Binelli (2015), implying an elasticity of substitution between different types of human capital of 11.5; the capital share of output is estimated at 0.372, close to the 0.4 value that is often used in economic literature for developed countries; and $\rho_2$ is estimated at an implausible value of 1.047.

To address the existence of sources endogeneity other than total factor productivity, this paper uses the number of classrooms for each education level as instrumental variables for the ratio of different types of labour supply at the municipal level. IV estimation relies on the assumption that the number of classrooms for different education levels in a municipality does not affect relative hourly earnings through any channel other than the relative labour supply. Results from IV estimation are shown in the Column (2) of Table 3.9. The productivity parameters, the capital share of income, and $\rho_2$ remain largely unchanged, whereas the $\rho_1$ parameter increases to 1.039, implying an implausible elasticity of substitution of -25.6.

As with the labour-related parameters of the production function, this paper adopts an IV strategy to estimate the parameters of the production function related to capital. Specifically, population is used as an instrument for the ratio of effective units of labour to the capital stock, following the work of Antras (2004). Results from GMM estimation without instrumental variables for labour-related parameters of the production function but with population as an instrument for the ratio of capital to effective units or labour are shown in Column (3) of Table 3.9. The 0.437 point estimate of the capital share of income remains close to the original estimate of 0.372, whereas the $\rho_2$ parameter changes from 1.047 to 0.886, implying an elasticity of substitution between physical capital and effective units of labour of 8.8.

Finally, column 4 of Table 3.9 shows the estimates that result when instruments are used in both stages of GMM estimation. Productivity estimates remain largely unchanged relative to the case where no instruments are used. The estimate of the capital share of income is also stable at around 0.4. However, estimates of $\rho_1$ and $\rho_2$ undergo important changes relative to Column (1). In particular, the $\rho_1$ estimate of 1.039 implies an elasticity of substitution between different types of human capital of -25.6. On the other hand, the $\rho_2$ estimate of 1.151 implies an elasticity of substitution between capital and labour of -6.6.

Overall, estimates of the productivity of different types of human capital are stable across the 4 specifications in the table and are estimated with high significance. In contrast, the capital income share and the parameters $\rho_1$ and $\rho_2$ are estimated imprecisely and fluctuate widely across all specifications. Hence, the paper disregards the estimated values of this later set of parameters and instead takes their values from the existing economic literature.

Regarding the value of the elasticity of substitution between physical and human capital, Ramírez-Verdugo (2006) estimates this parameter at 1.1 for Mexico, very close to Cobb-Douglas, while Mallick (2012) estimates the Mexican elasticity of substitution at a much lower 0.087. In both cases, physical and human capital act as complements in production and, therefore, both inputs are assumed to be complements in this paper. Specifically, capital and labour are assumed to be Cobb-Douglas, but the qualitative nature of the results in subsequent sections of the paper is not altered by this assumption.

Concerning the capital share of income, Barro and Sala-i Martin (2004) estimate this parameter at 0.69 for Mexico. Kehoe and Kehoe (1994) estimate the same share at 0.75. Garcıa-Verdú (2005) provides a corrected estimate for the capital share of income for Mexico of around 40 percent, which will be used in subsequent sections of this paper.

Finally, this paper uses the values estimated by Binelli (2015) for the elasticity of substitution between different types of human capital for the Mexican economy. She estimates the elasticity of substitution between higher and intermediate levels of education at 4.4 and the elasticity of substitution between skilled and unskilled human capital al 7.1, and argues that these results constitute evidence of greater complementarities between intermediate and higher levels of education.

### 3.4.3 Other parameters of the model

This paper uses the annual subjective discount factor to be 1.1, similar to the value of 1.0123 calibrated by Attanasio, Bonfatti, Kitao and Weber (2015) for the Latin America and Caribbean region to match the capital-output ratio of the region in 2010. The parameter $\gamma$ is set to 0.1, implying an elasticity of intertemporal substitution close to 1, in line with the consumption literature (see Attanasio 1999).

## 3.5 Policy Experiment

Using the estimated production function and the discrete choice model, this paper simulates the effect of an expansion of Mexican social policy, consisting of *Progresa* and other educational subsidies. Exposition begins by describing the policy experiment. Next, the paper turns to decomposing the effects of the policy expansion by schooling level. Finally, the last subsection describes how the conclusions drawn from the policy experiment vary with the parameters of the model.

### 3.5.1 Description of the policy experiment

This section of the paper evaluates the effects of a hypothetical policy shift consisting of an expansion of the existing government educational transfers to benefit 50 percent of the population currently not receiving benefits at each education level, under 3 alternative selection rules. First, the simulation considers a cream skimming selection rule, by which the government selects the people with the highest ATE conditional on their observable characteristics as the new beneficiaries, in addition to the people currently receiving cash transfers from the government. Second, the simulation considers the worst possible selection rule, by which the government selects people with the most negative ATE at each education level to take part in the programs in addition to the people that are currently benefited by them. Third, the simulation considers selecting new recipients with a socio-economic study, very much in the style in which beneficiaries of social policy are currently selected.

An expansion of the programs comprising Mexican social policy of the magnitude considered involves involves a number of new recipients equivalent to: 42 percent of the population in the age of starting college attendance, 34.2 percent of the population in the age of starting highschool; and 29.7 percent of the population in the age of starting elementary school.

The simulation starts at the steady state implied by the schooling choices made by the 1988, 1985, and 1982 cohorts of individuals in the *Censo de Población y Vivienda 2010*. In this steady state, 5 percent of the population chooses to terminate education after elementary school; 22 chooses to complete only elementary and middleschool; 29 completes highschool but does not progress to superior education, and 44 percent of the population attends college.

The transition paths of output, output growth, the number of effective units of labour (i.e., $Q_t$ in the model), the size of the workforce in the economy, physical capital, consumption, the average wage, investment, the relative wages for different schooling levels, and the physical capital rent are calculated using the methodology of Auerbach and Kotlikoff (1987). The transitional dynamics are studied assuming that the economy converges to the new steady state, implied by the policy shift, in less than 100 years.

Immediately after the implementation of the policy shift, no change occurs in the variables of interest, as a 12-year period is necessary for the first cohort benefited by the expansion to arrive to the age at which the first decision of whether to continue education is made. After year 12, both the size of the workforce and the effective units of labour in the economy fall, as a larger fraction of people decides to continue education and complete middleschool relative to previous years. This temporary decrease in the number of effective units of labour entails a shrinkage of physical investment and a reduction of the physical capital stock, since effective labour and physical capital are complements under the assumed value of the elasticity of substitution. Capital rent also shrinks because the marginal product of capital decreases when both the stock of physical capital and the effective units of labour fall. In consonance, output decreases. Interestingly, the average wage of the economy rises, since the wage bill is now divided among fewer workers. The ratio of the wage of workers with middle school education to the wage of workers with elementary school falls since the latter type of workers become scarcer in the economy. This initial change in relative wages is the direct consequence of the assumption that different types of human capital are substitutes and not complements in production. The same line of reasoning applies for the second and third cohorts benefited by the policy shift during years 13 and 14 after the expansion of *Progresa* and other social programs.

After 15 years, the members of the first cohort benefited by the policy shift that decided to continue education after completing elementary schooling face the decision of terminating their education once they complete middle school or progressing towards high school. The policy shift implies that a higher proportion of individuals will choose to continue their education relative to previous cohorts. Therefore, the total size of the workforce and the effective units of labour will fall further, implying as before a decrease in investment, capital sock, capital rent, and output, as well as an increase in average wage and a fall in the wage of individuals that terminated education after high school relative to the wage of individuals that only completed middle school education. The same line of reasoning applies for the second and third cohorts that were benefited after the policy shift.

Similarly, at year 18 after the implementation of the expansion of *Progresa* and other social programs, individuals of the first cohort benefited by the policy shift that decided to complete high school face the decision of terminating their education or obtaining a college degree. As a consequence of the above-mentioned expansion, more individuals decide to complete their college degree relative to previous cohorts. The immediate consequence of this change in terms of aggregate variables is the same as in years 12 and 15 after the policy implementation. The same line of reasoning applies for the second through fifth benefited cohorts.

After 23 years of the policy shift, all individuals of the first beneficiary cohort have finally entered the labour force, and the total workforce stops falling but remains below its initial level. The reason for a permanently lower workforce is that more individuals are studying and less individuals are working in every period relative to the initial steady state. Even though the total workforce is smaller than in the initial steady state, a higher level of educational attainment in the economy implies that the productivity of individuals is higher on average than before the policy shift and, therefore, the effective units of labour are higher than in the initial steady state. An increase in the number of effective units of labour is accompanied by an increase in physical investment, capital stock, and capital rent. The increase in the average wage is no longer solely explained by a decrease in the number of workers among which the wage bill is divided, but can be explained by higher individual wages for highschool and college graduates. The wage of the college-educated relative to the wage of the workers that completed only high school decreases, as more individuals have a college degree than in previous years. Similarly, the wage of the workers that completed highschool relative to the wage of middleschool workers falls, since more individuals decide to complete highschool relative to previous cohorts. Finally, the wage of middleschool workers relative to that of individuals without schooling falls, as more individuals choose to complete middle school than before the policy shift.

In subsequent years, all aggregate variables move gradually towards their new steady state levels due to the gradual displacement from the labour market of the older cohorts that were not benefited by the policy shift. The reason why aggregate variables in the economy reach the new steady state 75 years after the policy shift is because the first beneficiary cohort passes away and all subsequent cohorts continue to benefit by the expansion of *Progresa* and other social programs. Hence, the incentives faced by all cohorts alive 75 years after the policy shift are the same, and their schooling decisions are the same on average.

Aggregate consumption deserves a special mention, as this variable increases slowly over the initial 40 years after the policy shift, and the majority of the increase in consumption towards the new steady state takes place during years 40 to 80 after the policy expansion. The reason for this gradual change in consumption is that individuals consume more at older ages: even though human capital accumulation increases wages early in the working life, individuals increase their savings to afford higher consumption later in life.

Figure 3.5 depicts the trajectory of the variables of interest in the economy. The blue line depicts the trajectory that the variables follow if the cream-skimming selection rule is used by the government, while the green lines depict the trajectory of the variables if the worst possible selection rule is used. The red line depicts the trajectory that variables would follow if the current selection rule, which is based on the results of socio-economic study, is used to select new recipients. In general, usage of a better selection rule results in more abrupt changes in the variables of interest before reaching the final steady state. Also, usage of the "cream skimming" selection rule results in a final steady state level of output and consumption that is around 6 percentage points higher than the level achieved with the worst possible selection rule. Similarly, the effective units of labour in the new steady state are around 8 percentage points higher when the "cream skimming" selection rule is used instead of the worst possible selection rule.

An important annotation is that even when the “cream skimming” selection rule is used to select social policy beneficiaries, output only increases by 10 percentage points over a period of 75 years. Output grows at a yearly rate of 0.3 percent when output growth is fastest over the period under consideration and grows at a negative rate between years 12 and 23 after the policy is implemented. Similarly, average wage increases by 15 percentage points over a period of 75 years, and the average annual growth rate of the average wage is only 0.2 percent. These modest figures imply that generalized increases in education might not result in sizeable increases in output or in average wages, even though education investments are profitable in the long run.

### 3.5.2 Decomposition of the effects by schooling level

Next, the paper examines at which education level the public investment of funds results in more significant gains for the economy. Figure 3.4 depicts the trajectories of the variables of interest observed after an expansion of *Progresa* and other social policy programs to cover 50 percent of the individuals currently not benefited by them, under the assumption that the new beneficiaries are selected with a socio-economic study. The blue lines show the trajectories that would be followed by the variables of interest were the expansion to take place only in programs aimed at increasing college attendance; the green lines show the trajectories that would be observed if the expansion corresponded to programs aimed at increasing high school attendance; and the red lines show the trajectories that would be followed by the variables of interest if only programs aimed at increasing middle school attendance were expanded.

As revealed by the figure, an expansion of social policy programs aimed at increasing college attendance would result in the highest benefit for society, followed by an expansion of the programs aimed at increasing high school attendance. A further expansion of social policy programs aimed at increasing middle school attendance would result in a very slight improvement in the variables of interest. In particular, the expansion of programs oriented towards increasing college attendance results in a 4.8 percent increase in output and a 6.1 percent increase in average wage over 75 years, and the expansion of highschool-oriented program results in a 2.7 increase in output and a 4 increase in the average wage, whereas the expansion of programs oriented towards increasing middleschool attendance results only in a 0.2 percent increase in output and a 0.5 percent increase in the average wage. The reason is that highschool and college programs have a higher ATE and therefore are more successful in changing school attendance decisions, whereas programs oriented towards middleschool have a lower ATE and face greater difficulties in providing an incentive for individuals to favourably change their attendance decisions.

Educational programs aimed at increasing highschool and college attendance are also more successful in increasing the productivity of individuals. The expansion of programs aimed at increasing college attendance results in a decrease of the workforce of 1.2 percent due the fact that after the policy shift new cohorts spend more time studying, but this decrease in the workforce results in an increase of 5.9 percent in the effective units of labour. Similarly, the expansion of programs aimed at increasing highschool attendance results in a decrease of 1.3 percent in the workforce and an increase of 3.6 percent in the effective units of labour. In contrast, the expansion of programs aimed at increasing middleschool attendance results in a decrease of 0.4 percent in the workforce and an increase of 0.5 percent in the effective units of labour.

### 3.5.3 Sensitivity analysis

This subsection tests the sensitivity of the above results to changes in the assumed values of the model parameters. The elasticity of substitution between different types of human capital was estimated imprecisely earlier in the paper, and the study of this elasticity in Mexico in the economic literature is almost non-existing, with the exception of the seminal work of Binelli (2015). For this reason, Figure 3.6 provides a sensitivity analysis of the results. In the figure, an expansion of *Progresa* and other social policy programs aimed at increasing school attendance is simulated. As before, 50 percent of the individuals that currently do not receive social policy benefits become beneficiaries in the simulation, under the assumption that a socio-economic study is used to select the new beneficiaries. In the figure, the blue lines represents the trajectories that would be followed by the variables of interest if different types of human capital were perfect substitutes; the green lines represent the trajectories that would be followed if different types of human capital were Cobb-Douglas in production; and the red lines represent the trajectories that would be followed if the different types of human capital were perfect complements.

Clearly, the results from the initial policy experiment depend crucially on the elasticity of substitution between different types of human capital. If different types of human capital are complements in production, then output, effective units of labour, average wage, consumption, and the capital stock would decrease in the new steady state after the policy shift. The deterioration of these variables would be more pronounced in the case of perfect complementarity than in the Cobb-Douglas case.

Intuitively, the reason for this reversal in the results relative to the initial policy experiment is that, when different types of human capital are complements, increases in one type of human capital come at the expense of decreases in the rest of the human capital types. Complementarity between different human capital types means that a balanced workforce is better for production than an unbalanced one. As individuals decide to become more more educated due to the policy shift, too many college and high school graduates join the workforce and too few non-educated workers and middle school graduates participate in the economy. This unbalance dampens the number of effective units of labour, which in turn implies a decrease in the steady-state capital stock. Thus, a lower capital stock level is reached in a new steady state after a period of disinvestment. Similarly, output decreases during the transition period until the new, lower steady-state output is reached. Average wage decreases throughout the transition period due to a falling marginal productivity of labour associated to imbalances in the workforce. Capital rent decreases due to the physical disinvestment process paired with a drop in the effective units of labour. Since both the effective units of labour and physical capital decrease by roughly the same amount in the new steady state, the capital rate comes back to unitary levels after the 75-years transition period.

Furthermore, when different types of human capital are perfect complements (Leontieff), production does not increase when individuals decide to become highly educated, simply because an equal increase in the number of people without a degree or with only elementary schooling would be required for this to be the case. With Leontieff production technology, the relative wage of the individuals with the more abundant type of human capital must be close to zero. Since workers without education or with only an elementary school degree become scarcer than workers with a middle school degree after the policy shift, the wage of the latter type of workers relative to the wage of the former must be close to zero. The same reasoning holds true when examining the relative wage of the individuals with a highschool degree and individuals with a middle school degree, as well as for the wage of the college-educated relative to the wage of workers with only a highschool degree.

## 3.6 Concluding Remarks

The present paper studies the general equilibrium effect of government educational transfers on middleschool, highschool, and college attendance using the methodology by Aakvik et al. (2005), with an structural model inspired by Attanasio et al. (2012). The paper estimates the parameters of the production function of the Mexican economy in a fashion similar to Heckman et al. (1998*a*). Estimation of the effect of *Progresa* and other existing social policy programs in Mexico on the attendance decisions of individuals and of the production function in the economy enables the simulation of the effect of policy shifts on the aggregate variables of the economy. In particular, an expansion of *Progresa* and other existing social policy programs to benefit 50 percent of the individuals currently not benefited by social policy results in a moderate effect on output (10 percent) and wages (15 percent) after 75 years of the shift implementation. The majority of the effect of social policy expansions on the aggregate variables of the economy arises as a consequence of programs aimed at increasing attendance in advanced education levels.

# Tables

Table 3.1: Characteristics of Mexican workers aged 15 and over between 1995 and 2015

| Variable | 1995<br>(1) | 2000<br>(2) | 2005<br>(3) | 2010<br>(4) | 2015<br>(5) |
|---|---|---|---|---|---|
| Number of workers (*N*) | 28,817,994 | 34,873,403 | 40,136,435 | 43,771,627 | 47,806,822 |
| *N* as a percentage of population | 31.6 | 35.5 | 37 | 38.4 | 39.6 |
| Demographic characteristics of workers | | | | | |
| Percentage of male | 69.6 | 67.3 | 64.5 | 63.5 | 63.3 |
| Average age | 35.9 | 36.3 | 37.9 | 38.6 | 39.5 |
| Percentage of married | 55.3 | 53.2 | 50.8 | 48.3 | 46.2 |
| Percentage of informal | 27.8 | 27 | 27.8 | 28.2 | 26.6 |
| Average years of schooling | 7.4 | 8.2 | 8.7 | 9.2 | 9.6 |
| Distribution of workers by education | | | | | |
| General modality | | | | | |
| No degree | 30.8 | 24.8 | 20.6 | 16.7 | 13 |
| Elementary (primaria) | 25.6 | 24.7 | 22.4 | 20.6 | 19.2 |
| Middle school (secundaria) | 18.3 | 21.9 | 25.9 | 28.3 | 30.3 |
| High school (preparatoria) | 6.4 | 8.5 | 11.7 | 14.2 | 17.1 |
| College or more | 9 | 11.9 | 14 | 15.2 | 16.5 |
| Technical modality | | | | | |
| Middle school | .93 | .51 | .45 | .31 | .14 |
| High school | 7.4 | 5.9 | 4.6 | 4.2 | 3.3 |
| Tertiary education & more | 1.46 | 1.78 | .4 | .45 | .48 |
| Distribution of workers by activity | | | | | |
| Construction | 7.8 | 8.6 | 8.5 | 8.4 | 8.3 |
| Manufacturing | 16.9 | 20.3 | 17 | 15.4 | 16.3 |
| Commerce | 17.5 | 16.7 | 18.6 | 19.2 | 18.4 |
| Services | 32.3 | 33.6 | 35.9 | 38.3 | 38.4 |
| Agriculture | 19.2 | 14.6 | 12.8 | 12 | 12.2 |
| Electricity & energy | .7 | .9 | .9 | .9 | .9 |
| Communications & transports | 5.6 | 5.3 | 5.5 | 5.2 | 5.1 |
| Distribution of workers by occupation | | | | | |
| Professional | 6.9 | 7.4 | 7.6 | 8.7 | 10 |
| Teacher (education) | 3.9 | 3.8 | 4.2 | 4.1 | 3.9 |
| Directing position | 2.5 | 2.5 | 2.2 | 2.2 | 1.8 |
| Office worker | 9 | 9.3 | 9.7 | 9.2 | 8.4 |
| Industry worker | 25 | 29 | 27.1 | 25.7 | 25.7 |
| Merchant | 16 | 14.8 | 16.9 | 17.4 | 17 |
| Transport operator | 5.1 | 4.9 | 5 | 5.1 | 5.3 |
| Personal services | 11.2 | 11.9 | 12.7 | 13.6 | 14.9 |
| Protection or vigilance | 2 | 2.1 | 2.3 | 2.3 | 1 |
| Agriculture worker | 18.4 | 14.2 | 12.3 | 11.7 | 11.9 |
| Distribution of workers by region | | | | | |
| Border | 18.1 | 18.7 | 18.6 | 18.3 | 19 |
| North | 8.8 | 9.7 | 10 | 9.9 | 10.1 |
| Center | 32.9 | 33.1 | 33.4 | 33.5 | 33.4 |
| Capital | 25.7 | 23.6 | 23 | 22.8 | 22.4 |
| South | 14.5 | 14.9 | 15 | 15.5 | 15 |

**Sources:** *Encuesta Nacional de Empleo (ENE)* for years 1995 and 2000, and *Encuesta Nacional de Ocupación y Empleo (ENOE)* for years 2005, 2010, and 2015. Data for all years corresponds to the second quarter of the year, except for 2000, when it correponds to the fourth quarter.
**Notes:** Informal workers are those that do not pay labour income taxes and are not entitled to receive social security benefits. The states of the country are divided into regions. The border region includes all states that border with the US (Baja California, Coahuila, Chihuahua, Nuevo León, Sonora, and Tamaulipas); the north region includes states that located at latitudes higher than that of Mexico City (Aguascalientes, Baja California Sur, Durango, Nayarit, San Luis Potosí, Sinaloa, and Zacatecas); the center region includes states in latitudes similar to that of Mexico City (Colima, Guanajuato, Hidalgo, Jalisco, Michoacán, Morelos, Puebla, Querétaro, Tlaxcala, Veracruz); the capital region includes Mexico City and its metropolitan area (Distrito Federal and México); and the south region includes the remaining states (Campeche, Guerrero, Oaxaca, Quintana Roo, Tabasco, and Yucatán).

Table 3.2: Summary statistics of the schools in Mexico for the 2014-2015 academic year

| | Preschool (1) | Elementary (2) | Middle (3) | High (4) | College (5) | Postgraduate (6) | Other (7) |
|---|---|---|---|---|---|---|---|
| Schools | 95,449 | 101,299 | 36,970 | 18,262 | 6,088 | 705 | 7,116 |
| Students | 4,785,742 | 14,349,214 | 5,688,856 | 3,778,398 | 3,312,460 | 41,329 | 1,633,132 |
| | [50.1] | [141.6] | [153.8] | [206.8] | [544] | [58.6] | [229.5] |
| | (57.3) | (161) | (192.3) | (431) | (1402.5) | (114.6) | (842.3) |
| Teachers | 228,762 | 574,208 | 346,124 | 240,659 | 362,123 | 15,058 | 44,425 |
| | [2.3] | [5.6] | [9.3] | [13.1] | [59.4] | [21.3] | [6.2] |
| | (2) | (4.9) | (10.4) | (34.7) | (147.8) | (25.2) | (10.4) |
| Classrooms | 211,418 | 566,685 | 205,260 | 107,671 | 104,978 | 4,084 | 9,219 |
| | [2.2] | [5.5] | [5.5] | [5.8] | [17.2] | [5.7] | [1.2] |
| | (2.2) | (5.1) | (4.8) | (7.7) | (28) | (10.8) | (2.8) |

**Sources:** *Secretaría de Educación Pública (SEP).*
**Notes:** Unbracketted numbers are totals, numbers enclosed in brackets are means at the school level, and numbers enclosed in parentheses are the corresponding standard deviations.

Table 3.3: Selection equation for social policy beneficiaries at different schooling levels

| Covariate | Middle school (1) | High school (2) | College (3) |
|---|---|---|---|
| Gender (male) | -0.029* | -0.146*** | -0.119*** |
| | (0.018) | (0.02) | (0.028) |
| | [-0.006] | [-0.031] | [-0.02] |
| Indigenous | 0.232*** | 0.162*** | 0.068* |
| | (0.025) | (0.027) | (0.04) |
| | [0.047] | [0.034] | [0.011] |
| Socioeconomic study | 0.598*** | 0.511*** | 0.389*** |
| | (0.021) | (0.022) | (0.03) |
| | [0.122] | [0.108] | [0.066] |
| Rural locality | -0.029* | -0.146*** | -0.119*** |
| | (0.018) | (0.02) | (0.028) |
| | [-0.006] | [-0.031] | [-0.02] |
| Locality underdevelopment index (IRS) | 0.513*** | 0.384*** | 0.237*** |
| | (0.013) | (0.015) | (0.021) |
| | [0.105] | [0.081] | [0.04] |
| Observations | 46,489 | 38,604 | 25,540 |

**Sources:** Own elaboration with data from the *Censo de Poblacion y Vivienda 2010*.
**Notes:** Numbers in rectangular bracketts are marginal effects, numbers in parentheses are standard deviations, and unbracketted numbers are point estimates. State dummies are included in each regression. * indicates significancy at the 10 percent level, ** indicates significancy at the 5 percent level, and *** significancy at the 1 percent level.

Table 3.4: Individual unobserved heterogeneity coefficients

| Parameter | Middle school (1) | High school (2) | College (3) |
|---|---|---|---|
| $\alpha_1$ | -0.742 | -6.192** | 0.501 |
| | (0.622) | (2.211) | (0.498) |
| | [-0.141] | [-0.23] | [0.08] |
| $\alpha_0$ | 5.26*** | 3.283*** | -2.789*** |
| | (0.847) | (0.377) | (0.293) |
| | [0.014] | [0.072] | [-0.025] |
| Observations | 46,489 | 38,604 | 25,540 |

**Sources:** Data from the *Censo de Poblacion y Vivienda 2010*.
**Notes:** Numbers in rectangular bracketts are marginal effects, numbers in parentheses are standard deviations, and unbracketted numbers are point estimates. State dummies are included in each regression. * indicates significancy at the 10 percent level, ** indicates significancy at the 5 percent level, and *** significancy at the 1 percent level.

Table 3.5: Attendance equations for different schooling levels

| Covariate | Middle school | | High school | | College | |
|---|---|---|---|---|---|---|
| | $Y_0$ | $Y_1$ | $Y_0$ | $Y_1$ | $Y_0$ | $Y_1$ |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Gender (female) | -0.288** | 0.056 | 0.236*** | 0.068 | -0.149** | - 0.097* |
| | (0.097) | (0.066) | (0.053) | (0.222) | (0.053) | (0.061) |
| | [-0.007] | [0.001] | [0.022] | [0] | [-0.017] | [-0.025] |
| Indigenous | 0.146 | 0.081 | -0.344*** | 0.395 | -0.307*** | 0.083 |
| | (0.126) | (0.086) | (0.078) | (0.337) | (0.081) | (0.084) |
| | [0.004] | [0.001] | [-0.032] | [0.002] | [-0.034] | [0.022] |
| Locality underdevelopment index (IRS) | -0.162** | -0.045 | -0.146*** | -0.073 | -0.655*** | 0.039 |
| | (0.079) | (0.068) | (0.044) | (0.15) | (0.071) | (0.069) |
| | [-0.004] | [-0.001] | [-0.013] | [0] | [-0.073] | [0.01] |
| Education of the head of household | | | | | | |
| Elementary | 1.188*** | 0.163** | 0.873*** | 1.115*** | 0.465*** | 0.16** |
| | (0.109) | (0.087) | (0.075) | (0.354) | (0.081) | (0.076) |
| | [0.03] | [0.002] | [0.08] | [0.005] | [0.052] | [0.042] |
| Middle school | 3.164*** | 0.237** | 1.884*** | 1.274*** | 1.071*** | 0.34*** |
| | (0.33) | (0.112) | (0.113) | (0.37) | (0.118) | (0.092) |
| | [0.081] | [0.003] | [0.173] | [0.006] | [0.12] | [0.088] |
| High school | 4.655*** | 0.312* | 3.603*** | 1.967*** | 1.896*** | 0.471*** |
| | (0.79) | (0.199) | (0.368) | (0.508) | (0.201) | (0.137) |
| | [0.12] | [0.004] | [0.332] | [0.009] | [0.212] | [0.123] |
| College | 5.407*** | 0.523** | 4.651*** | 3.754** | 3.011*** | 0.44*** |
| | (0.861) | (0.299) | (0.41) | (1.828) | (0.278) | (0.134) |
| | [0.139] | [0.007] | [0.428] | [0.017] | [0.337] | [0.114] |
| Locality with 2,500-14,999 inhabitants | 0.142 | 0.122 | 0.7020*** | 0.849*** | 0.6830*** | -0.085 |
| | (0.119) | (0.132) | (0.073) | (0.268) | (0.087) | (0.114) |
| | [0.004] | [0.002] | [0.065] | [0.004] | [0.076] | [-0.022] |
| Locality with 15,000-99,999 inhabitants | 0.379** | 0.098 | 0.758*** | 0.8010** | 0.991*** | -0.024 |
| | (0.168) | (0.18) | (0.095) | (0.364) | (0.124) | (0.141) |
| | [0.01] | [0.001] | [0.07] | [0.004] | [0.111] | [-0.006] |
| Locality with 100,000 or more inhabitants | 0.31* | 0.101 | 0.707*** | 0.174 | 0.867*** | -0.101 |
| | (0.208) | (0.235) | (0.109) | (0.455) | (0.124) | (0.169) |
| | [0.008] | [0.001] | [0.065] | [0.001] | [0.097] | [-0.026] |
| Observations | 46,489 | 46,489 | 38,604 | 38,604 | 25,540 | 25,540 |

**Sources:** Data from the *Censo de Poblacion y Vivienda 2010*.
**Notes:** Numbers in rectangular bracketts are marginal effects, numbers in parentheses are standard deviations, and unbracketted numbers are point estimates. State dummies are included in each regression. * indicates significancy at the 10 percent level, ** indicates significancy at the 5 percent level, and *** significancy at the 1 percent level.

Table 3.6: Mean and distributional treatment parameters by school level

| | Middle school (1) | High school (2) | College (3) |
|---|---|---|---|
| ATE, or $E[\Delta]$ | .052 | .26 | .308 |
| | (.046) | (.143) | (.204) |
| Distributional version of ATE | | | |
| $\Pr(\Delta = 1)$ | .058 | .271 | .448 |
| $\Pr(\Delta = 0)$ | .937 | .719 | .412 |
| $\Pr(\Delta = -1)$ | .005 | .011 | .14 |
| TT, or $E[\Delta \vert D = 1]$ | -.001 | .046 | .79 |
| | (.023) | (.108) | (.113) |
| Distributional version of TT | | | |
| $\Pr(\Delta = 1 \vert D = 1)$ | .011 | .083 | .808 |
| $\Pr(\Delta = 0 \vert D = 1)$ | .976 | .879 | .174 |
| $\Pr(\Delta = -1 \vert D = 1)$ | .013 | .037 | .018 |
| MTE with $Z\beta_D = 2$, or $E[\Delta \vert Z\beta_D = 2]$ | .136 | .433 | -.122 |
| | (.113) | (.172) | (.131) |
| Distributional version of MTE with $Z\beta_D = 2$ | | | |
| $\Pr(\Delta = 1 \vert Z\beta_D = 2)$ | .136 | .433 | .097 |
| $\Pr(\Delta = 0 \vert Z\beta_D = 2)$ | .864 | .567 | .684 |
| $\Pr(\Delta = -1 \vert Z\beta_D = 2)$ | 0 | 0 | .219 |
| MTE with $Z\beta_D = 0$, or $E[\Delta \vert Z\beta_D = 0]$ | .012 | .16 | .23 |
| | (.015) | (.117) | (.176) |
| Distributional version of MTE with $Z\beta_D = 0$ | | | |
| $\Pr(\Delta = 1 \vert Z\beta_D = 0)$ | .014 | .161 | .312 |
| $\Pr(\Delta = 0 \vert Z\beta_D = 0)$ | .984 | .839 | .605 |
| $\Pr(\Delta = -1 \vert Z\beta_D = 0)$ | .002 | 0 | .082 |
| MTE with $Z\beta_D = -2$, or $E[\Delta \vert Z\beta_D = -2]$ | -.01 | -.005 | .532 |
| | (.006) | (.014) | (.107) |
| Distributional version of MTE with $Z\beta_D = -2$ | | | |
| $\Pr(\Delta = 1 \vert Z\beta_D = -2)$ | 0 | .02 | .547 |
| $\Pr(\Delta = 0 \vert Z\beta_D = -2)$ | .989 | .956 | .437 |
| $\Pr(\Delta = -1 \vert Z\beta_D = -2)$ | .011 | .024 | .016 |

**Source:** Elaboration with data from the *Censo Nacional de Población y Vivienda.*

Table 3.7: Marginal effects of regressors on mean treatment parameters of Mexican social policy

| | $E_X\left[\frac{\partial E[\Delta \vert X=x]}{\partial x_k}\right]$ | | | $E_X\left[\frac{\partial E[\Delta \vert X=x]}{\partial x_k} \vert D=1\right]$ | | |
|---|---|---|---|---|---|---|
| | Middle school (1) | High school (2) | College (3) | Middle school (4) | High school (5) | College (6) |
| Gender | -.007 | .02 | .007 | -.003 | -.003 | .062 |
| Indigenous | -.002 | .032 | .056 | .006 | .033 | .001 |
| IRS | .003 | .013 | .085 | .009 | .034 | -.064 |
| Parental education | | | | | | |
| Elementary school | -.024 | -.072 | -.013 | -.001 | -.013 | -.007 |
| Middle school | -.066 | -.16 | -.037 | -.008 | -.049 | -.021 |
| High school | -.098 | -.308 | -.098 | -.013 | -.103 | -.057 |
| College | -.112 | -.392 | -.233 | -.011 | -.111 | -.138 |

**Source:** Own elaboration with data from *Censo de Población y Vivienda 2010.*

Table 3.8: Cream skimming correlations for Mexican social policy at different education levels

| | Middle school (1) | High school (2) | College (3) |
|---|---|---|---|
| Corr$(U_1, U_0)$ | -.585 | -.944 | -.422 |
| Corr$(U_D, U_0)$ | .695 | .676 | -.666 |
| Corr$(U_D, U_1)$ | -.421 | -.698 | .317 |
| | | | |
| Corr$(X\beta_0, X\beta_1)$ | .21 | .05 | .216 |
| Corr$(Z\beta_D, X\beta_0)$ | -.56 | -.563 | -.612 |
| Corr$(Z\beta_D, X\beta_1)$ | -.15 | -.023 | -.075 |
| | | | |
| Corr(Pr$(Y_1 = 1\|X)$, Pr$(Y_0 = 1\|X)$) | .523 | .754 | .26 |
| Corr(Pr$(D = 1\|Z)$, Pr$(Y_0 = 1\|X)$) | -.513 | -.584 | -.594 |
| Corr(Pr$(D = 1\|Z)$, Pr$(Y_1 = 1\|X)$) | -.343 | -.5 | .015 |
| | | | |
| Corr$(Y_1^*, Y_0^*)$ | -.036 | .754 | .26 |
| Corr$(D^*, Y_0^*)$ | .013 | .018 | -.245 |
| Corr$(D^*, Y_1^*)$ | -.177 | -.007 | .131 |
| | | | |
| Corr$(Z\beta_D, X(\beta_1 - \beta_0))$ | .455 | -.008 | .606 |
| Corr(Pr$(D = 1\|Z)$, $E[\Delta\|X]$) | .507 | .581 | .615 |
| Corr$(U_D, U_1 - U_0)$ | .031 | .05 | -.077 |
| Corr$(D^*, Y_1^* - Y_0^*)$ | -.019 | 0 | .083 |

Table 3.9: Estimates of the Mexican aggregate production function in 2014

| Parameter | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| *First stage (diffent types of human capital)* | | | | |
| No degree or elementary school productivity ($a_1$) | 0.186 ** | 0.175 | 0.186** | 0.175 |
| | (0.083) | (0.209) | (0.083) | (0.209) |
| Middle school productivity ($a_2$) | 0.202 * | 0.187 | 0.202* | 0.187 |
| | (0.104) | (0.259) | (0.104) | (0.259) |
| High school productivity ($a_3$) | 0.227*** | 0.226*** | 0.227*** | 0.226*** |
| | (0.063) | (0.072) | (0.063) | (0.072) |
| College productivity ($a_4$) | 0.385** | 0.412 | 0.385** | 0.411 |
| | (0.178) | (0.415) | (0.178) | (0.415) |
| Elasticity of substitution parameter ($\rho_1$) | 0.913 | 1.039 | 0.913 | 1.039 |
| | (0.764) | (2.160) | (0.764) | (2.160) |
| *Second stage (labour and capital)* | | | | |
| Capital share of output ($b$) | 0.372 | 0.317 | 0.437 | 0.420 |
| | (2.659) | (2.463) | (9.554) | (8.660) |
| Elasticity of substitution parameter ($\rho_2$) | 1.047 | 1.061 | 0.886 | 1.151 |
| | (1.300) | (1.289) | (4.629) | (4.247) |

**Sources:** *Encuesta Nacional de Ocupación y Empleo* (ENOE) of the second quarter of 2014, administrative data of the Mexican education ministry (SEP) on the number of college classrooms at the municipality level, and capital stock data at the municipality level from the 2014 economic census carried out by the Mexican institute of statistics (INEGI).

**Notes:** The column (1) of the table shows the results from simple GMM estimation; column (2) shows the results from using the number of classrooms for different education levels at the municipal level as instrumental variable for the ratios of different types of workers; column (3) shows the results from using the municipality population as an instrument for the labour-capital ratio in the second stage of GMM estimation, following Antras (2004); and column (4) shows the results from using instrumental variables in both stages. Standard errors are corrected for two-stage estimation as in Newey and McFadden (1994). The identity matrix was chosen as weighting matrix for GMM estimation in all cases. The symbol * indicates significancy at the 5 percent level. Means are unbracketted and standard deviations are between parentheses. The number of observations in each regression is 287.

# Figures

Figure 3.2: Distributional average treatment effects on attendance by schooling level in 2010

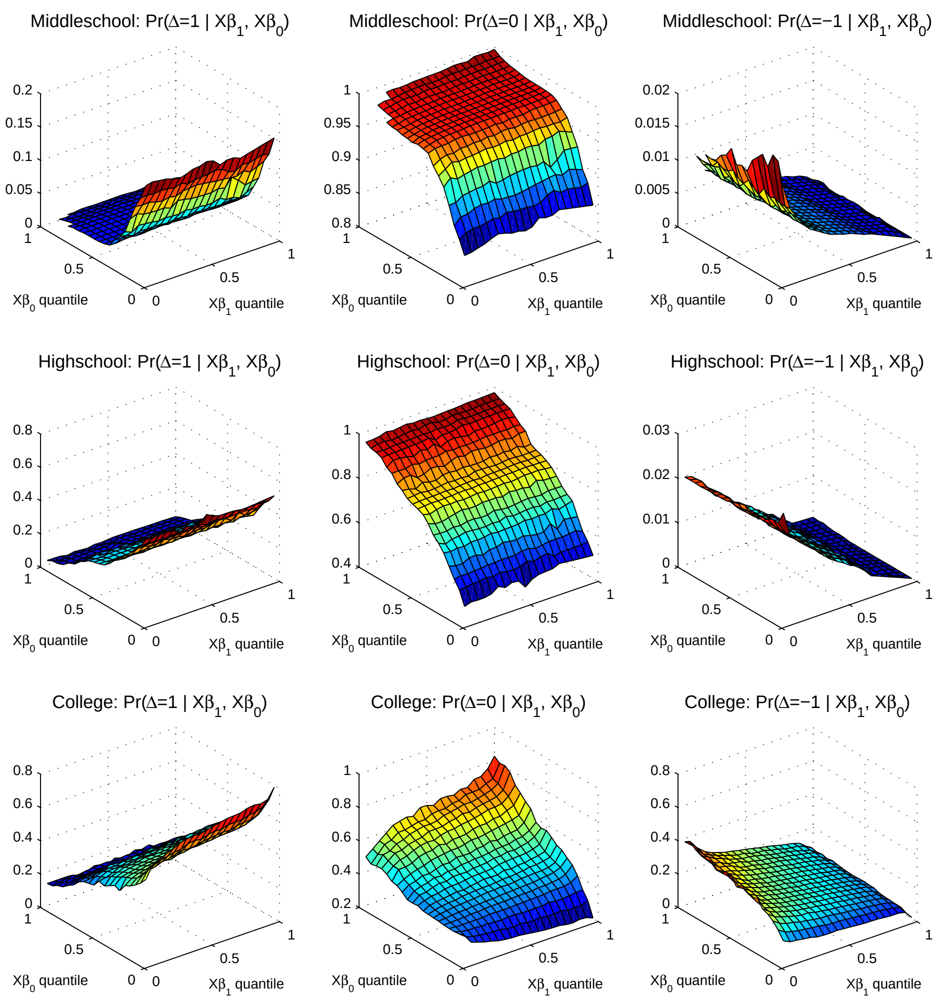


Figure 3.3: Marginal treatment effect of social policy by schooling level in 2010

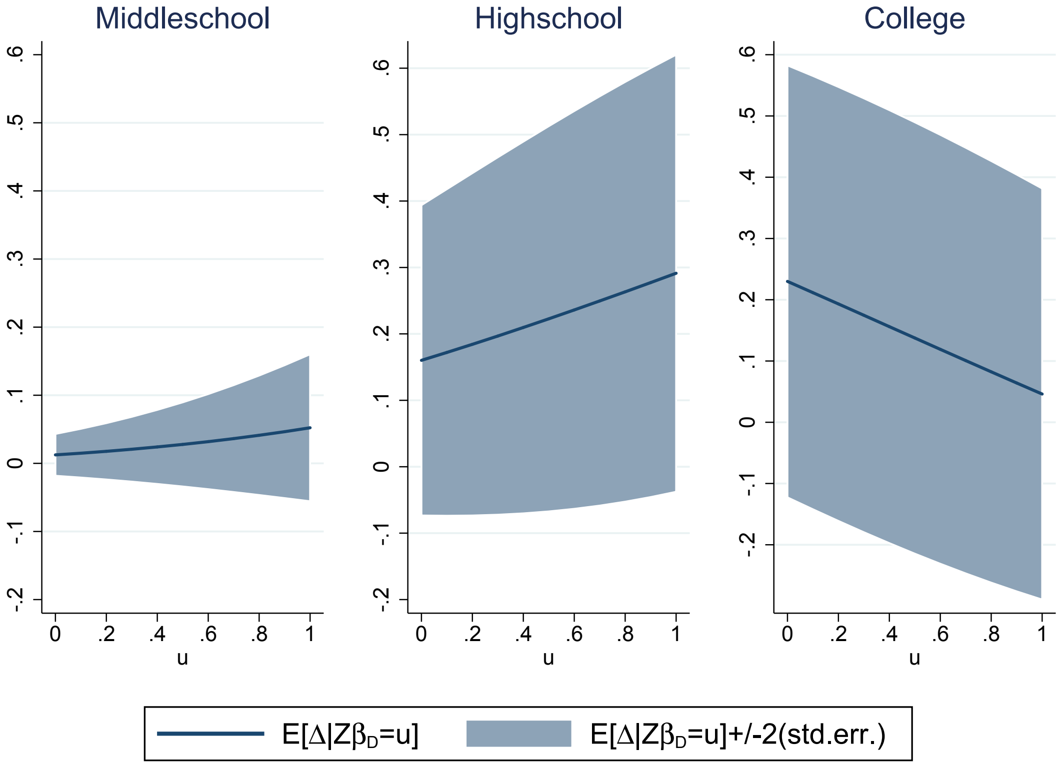


Figure 3.4: Impulse-response functions of the variables of the model to different social policy shifts

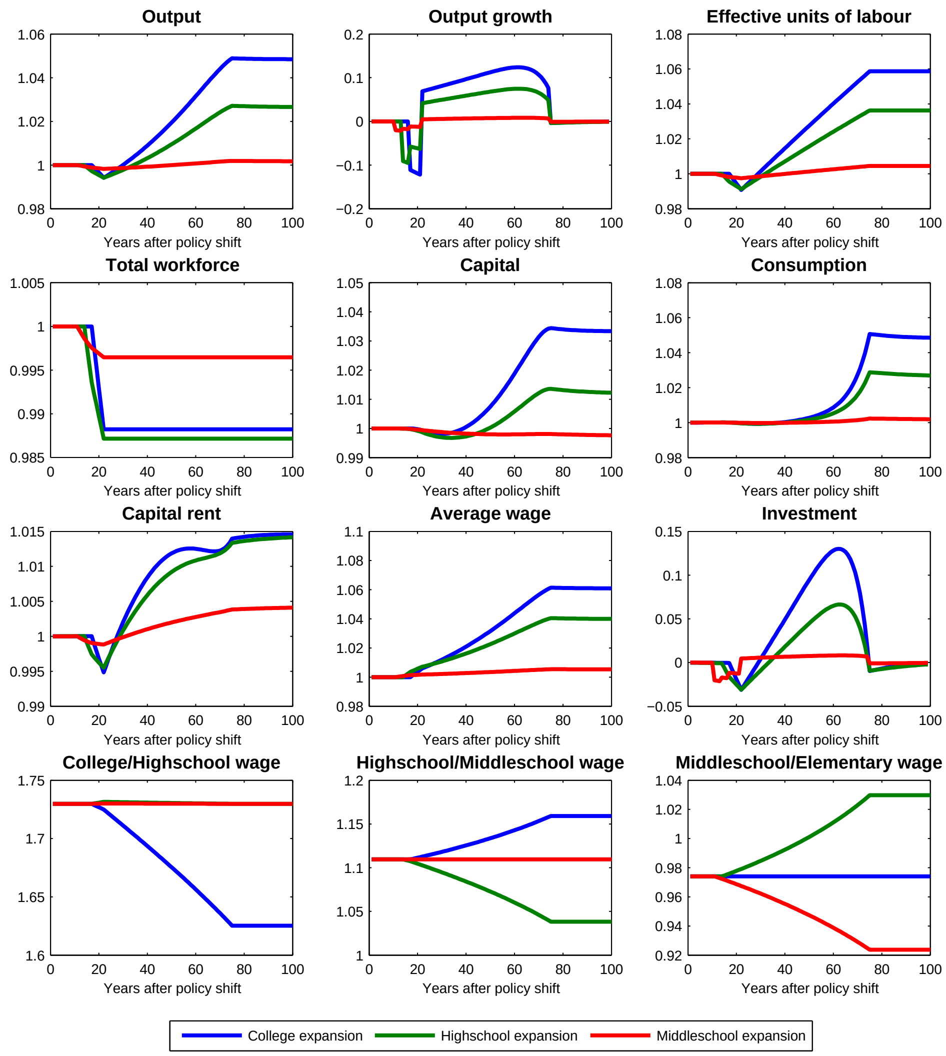


Figure 3.5: Impulse-response functions for different beneficiary households selection rules

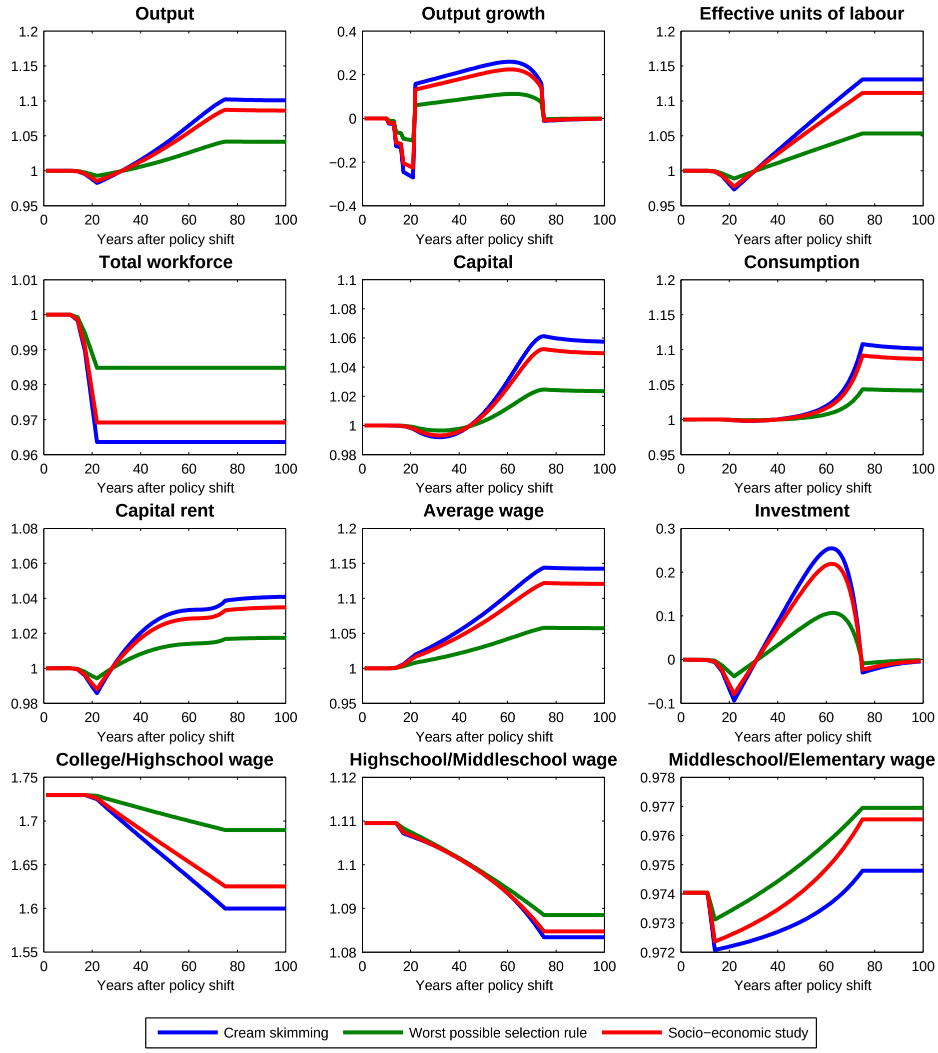
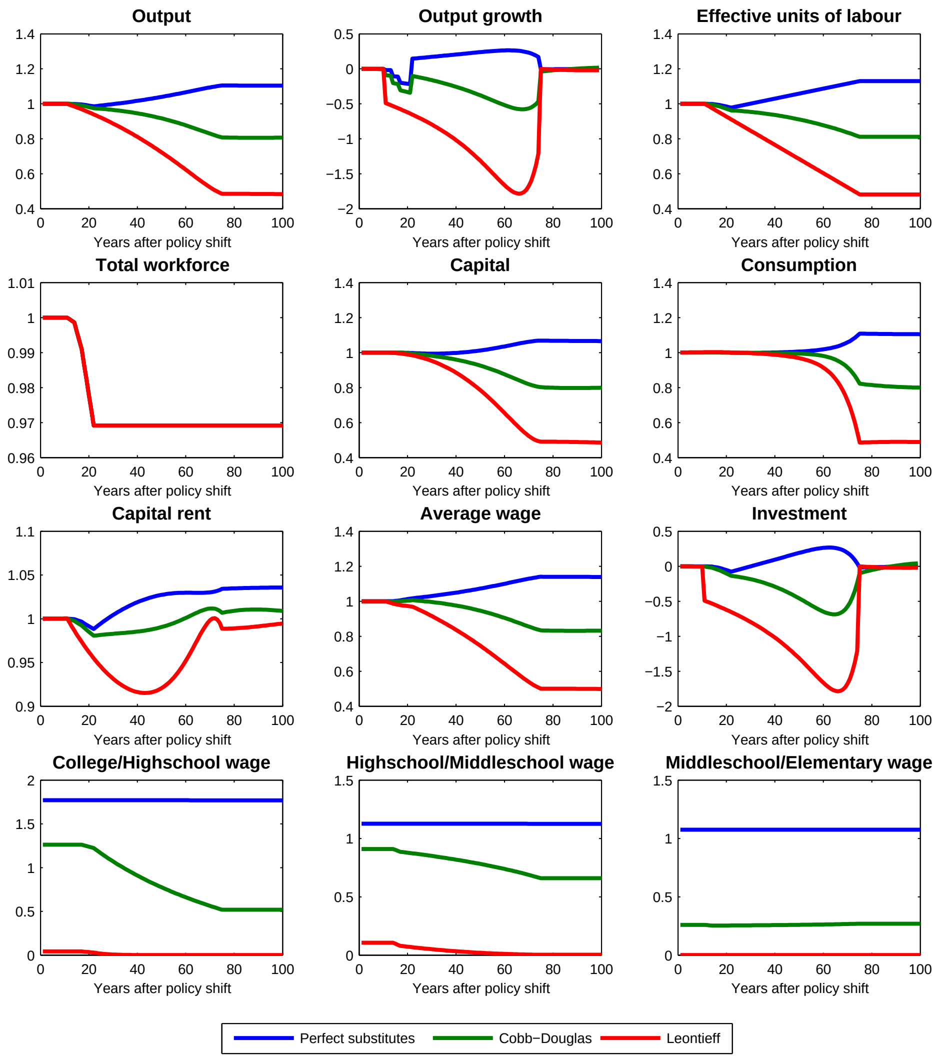


Figure 3.6: Sensitivity analysis: different elasticities of substitution between human capital types



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# Note on Co-authored Work

Notes on the joint work in Manuel Alejandro Estefan Davila's thesis "Essays on Development Economics":

- Chapter 1 is single-authored by Manuel Alejandro Estefan Davila
- Chapter 2, "Property Tax Compliance in Developing Countries: Evidence from Mexico", is co-authored between Anne Brockmeyer, Manuel Alejandro Estefan Davila, Karina Ramirez and Juan Carlos Suarez-Serrato, and each author contributed equally to the paper
- Chapter 3 is single-authored by Manuel Alejandro Estefan Davila