Three Essays In Policy Evaluation

by

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This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Statement of Contributions

Statement of Contributions

Andrés Arcila-Vasquez was the sole author for Chapter 2, which was written under the supervision of Dr. Ana Ferrer and was not written for publication.

This thesis consists in part of 2 manuscripts written for publication. Exceptions to sole authorship of material are as follows:

Research presented in Chapter 1:

This research was conducted at the University of Waterloo by Andrés Arcila-Vasquez under the supervision of Dr. Tao Chen., and Dr. Xiaolan Lu. Dr. Xiaolan Lu provided the information from the COPERT 4 model as well as descriptive statistics from emissions and the Air Quality Index. Dr. Tao Chen provided the information of registers of cars in China. Andrés Arcila-Vasquez was the primary coder and lead data analyst, and wrote the draft manuscripts.

Research presented in Chapter 3:

This research was conducted at the SWODRC at the University of Waterloo by Andrés Arcila-Vasquez under the supervision of Dr. Thomas Parker. Dr. Thomas Parker participated in coding, and designed the study. Andrés Arcila-Vasquez was the primary coder and lead data analyst, and wrote the draft manuscripts, which all co-authors contributed intellectual input on.

As lead author of these three chapters, I was responsible for contributing to conceptualizing study design, carrying out data collection and analysis, and drafting and submitting manuscripts. My coauthors provided guidance during each step of the research and provided feedback on draft manuscripts.

Abstract

This thesis consists of three chapters that study the effect of public policy on several economic and environmental outcomes. In the first chapter, we investigate the effect of a change in tax policy affecting cars on car pollutant emissions. We construct a data set on emissions using the COPERT 4 model, which was developed by the European Environmental Agency and is now widely used in environmental engineering to estimate emissions. The new tax impacted high cylinder vehicles with engine sizes larger than 3 liters while taxes on small cylinder cars remained unchanged. The COPERT model uses general information about infrastructure and certain driving conditions to calculate total emissions by engine size. We use a difference in difference methodology and exploit the variation introduced by the policy that deferentially affected cars with larger engines. By imposing a tax on larger engines, the share of these in the market should decrease while the other group should increase, therefore decreasing the emissions by the treated group. Our results showed that Particulate Matter and Carbon Monoxide emissions decreased by around 11%, while Volatile Compound and Nitric Oxide decreased by roughly 7%. These results are robust to the inclusion of province fixed effects, economic conditions and specific trends by province, different engine size trends as well as contamination by other possible policies.

In the second chapter, I use confidential micro files from the Canadian Labour Force Survey from 1994 to 2015 to assess whether the 2001 Quebec's affordable childcare policy changed the distribution of employment by occupation. In general, I found that the policy tended to reduce the concentration of male dominated occupations and increased the concentration of female dominated and gender balanced occupations. Comparing results at different levels of aggregation suggest that there were many occupational changes within the 3-digit occupation categories. These intra-occupational movements were likely driving the concentration of gender balanced occupations, whereas increased concentration in female dominated occupations was likely driven by inter-occupational movements from male dominated or gender balanced occupations. Further, I report less concentration of high-pay occupations and occupations requiring high levels of cognitive or social skills, but also lesser concentration in occupations requiring high levels of physical skills, after the policy. These effects tend to persist in the long run. This exercise highlights the need to further investigate

the distributional effects of the child care policy.

The third chapter is closely tied to the second chapter. Here, we use the same change in childcare policy to understand its effect on the overall skill distribution of jobs. We use newly developed methods to test for stochastic and Lorenz dominance and assess whether the distribution of skill requirements in occupations in Quebec is different before and after the policy relative to changes in the distribution of skills in the Rest of Canada. We complement this analysis by calculating Quantile Treatment Effects using a propensity score re-weighting technique to measure these differences across the distributions. Our results suggest that the distribution of the interpersonal, physical, visual and fine motor skills index in Quebec stochastically dominates the distribution of skills in the rest of Canada in 1994, whereas in 2004 the dominance is reversed. On the other side, the distribution of the analytical skill index in Quebec dominates the one for the rest of Canada in both years. The estimation of Quantile Treatment Effects strengthens these results by showing that the largest changes in the analytical skill index happened in occupations at the median ability level.

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Chapter 1

The Effectiveness of Consumption Tax on the Reduction of Car Pollution in China

Andres Arcila & Tao Chen & Xiaolan Lu

1.1 Introduction

Air pollution has ominous consequences on health. A study by the World Health Organization estimated that urban air pollution accounts for 6.4 million years of life lost worldwide annually (Cohen et al., 2004). Cars emit most of the pollutants associated with health deterioration. Currie and Walker (2011) estimated that the prenatal exposure to traffic congestion reduced welfare in the United Stated by $557 million per year and Ngo (2017) found evidence that maternal exposure to old buses in New York City is associated with reductions in birth weight and gestational ages at birth. Governments around the world have begun to respond to this problem through a variety of actions designed to mitigate the consequences of pollution. In this paper we study how a significant increase in a consumption tax paid on automobiles having a cylinder capacity larger than 3 liters affects emissions by exploiting exogenous variation from a natural experiment that took place in China.

It is well known that China has experienced steady and fast economic growth in the last several years. Average income has been increasing consistently, leading to growth in the consumption of durable goods by the middle class, especially cars, which are steadily increasing according to the China Association of Automobile Manufacturers. Production levels reached roughly 29 million cars in 2017, representing an increase of 3.16% from 2016 and effectively placing the country in first place for car production worldwide for the ninth consecutive year.

The increase in car consumption raised many concerns within the Chinese government, most notably the environmental consequences brought about through this massive circulation of new vehicles. In the first decade of the 2000s, the Chinese government implemented a series of policies that were both aimed to battle pollution emitted by cars and to tackle their consumption patterns by imposing a higher tax on bigger, more polluting automobiles.

This paper analyzes the impact of this policy on the total emissions of different pollutants using a difference in difference (DD) methodology. We construct a data set on emissions using the COPERT 4 model, which was developed by the European Environmental Agency and is now widely used in environmental engineering to estimate emissions. The new tax impacted high cylinder vehicles with engine sizes larger than 3 liters while taxes on small cylinder cars remained unchanged. Since the change in tax did not affect all cars, we have the ideal conditions in which to estimate the change in total emissions by high cylinder cars in comparison to smaller ones.

The COPERT model uses general information about infrastructure and certain driving conditions to calculate total emissions by engine size. One of the main concerns about the effectiveness of the DD results is the possibility of an anticipation effect by consumers in light of the upcoming policy change. That is, consumers might change their consumption behavior by discounting the possible change in the tax policy. We argue that the anticipation effect is unlikely to have a significant impact on our results because policies in China are not shared with the public and therefore consumers are unable to anticipate upcoming policy changes.

The identification in this paper comes from the fact that, by imposing a tax on cars with larger engines, the share of these in the market should decrease while the other group should increase, therefore decreasing the emissions by the treated group. These behavioral effects, that change the composition of the market shares of cars with small and large engine sizes, could also affect the driving conditions and the total distance travel by the cars. In order to estimate emissions we have to calibrate the model so that it matches the average distance traveled, temperature and other variables; as a result, the changes in the response by drivers might also have an effect on the total emissions.

Our results, therefore, should be considered in light of our departure from the assumption that people use their car at an average pace including policies that restrict circulation as described in Viard and Fu (2015). Even though these rules might affect total emissions, we believe that they are not substantial enough to significantly impact the emissions of large cars compared to small ones. There is extensive evidence that circulation restrictions induce substitution patterns among consumers who bypass the policy by purchasing new cheaper cars or used ones, thereby increasing pollution compared to its levels before policy implementation (see for example, (Carrillo et al., 2016; Davis, 2008)). In our study, we show that restriction policies are not driving our results, as they are robust to the inclusion of provinces that have implemented such policies.

The contributions of this paper are threefold. Firstly, we construct a novel data set on emissions that is calculated with a model that is widely used among environmental engineers and that can therefore be replicated in other setups and research questions. This is the first paper to take a more technical approach when estimating emissions by using information from road conditions in COPERT 4. This methodology allows us to effectively estimate emissions by cars, an advantage over the environment measures that can be contaminated by other sources of pollution. Our database can be used for this purpose as well as for other scenarios that require aggregate information from micro data.

Secondly, this research adds to the literature on taxation to reduce pollution. We show evidence to strengthen the work by Fullerton and West (2002), Adda and Cooper (2000), Li et al. (2009) and Engers et al. (2009), which all argue that automobile consumption taxes are policy tools that stimulate the consumption of low polluting commodities as they are more easily implemented than fuel taxes. Moreover, this document shows how policy makers can avoid the adverse consequences of pollution on health as found in Currie and Walker (2011), Ngo (2017), Ngo et al. (2018) and Chen and Whalley (2012) through the effective use of policy instruments.

Finally, to the best of our knowledge, we are the first to assess the effectiveness of this policy in terms of environmental outputs and policy implications. Our results show that there was indeed a significant change in environmental outputs in all the emissions factors that we consider. Furthermore, we extend the work by Zhao (2013) and Jiang (2009) who analyze the effect of this tax on the consumption of cars and its effect on overall pollution levels. This leads us to conclude that the policy was highly effective in reducing pollution by large cars in the country compared to small ones. The results are also robust in their inclusion of several control variables like province fixed effects and economic activity in the country. Likewise, we provide evidence on how the policy change affected the general emissions in the country by estimating a difference model for an Air Pollution Index.

The rest of the paper is organized as follows. Section 2 includes a literature review on environmental policy. Section 3 explains the policy change, its background and the data. Section 4 presents the econometric framework and the core of our results and section 5 concludes with some final comments.

1.2 Literature Review

There is much research on taxation to reduce pollution. It is a well known problem in public economics but there is still some divergence on how these types of taxes should be implemented. Fullerton and West (2002) argue that automobile consumption tax as a policy tool can stimulate the consumption of low polluting commodities to internalize pollution, which has more advantages than uniform fuel tax as it will produce the substitution effect in the automobile market structure in the long run. On this same line Adda and Cooper (2000); Li et al. (2009); Engers et al. (2009) claim that such tax has more advantages compared with other conventional policy tools, is more easily implemented than fuel taxes while also being more popular among the consumers. Additionally, the implementation of automobile consumption tax will produce the desired substitution effect of automobile market structure in the long run. At the same time, when buying a car, consumers often underestimate future fuel costs, thus deviating from the optimal choice, and making automobile consumption tax an effective supplement to fuel tax (Allcott and Wozny, 2014).

However, scholars who take a negative view pointed out that the automobile consumption tax will have a direct impact on the resource-intensive margin, as car buyers may choose to travel longer distance given the increase of low energy consumption of the vehicle. Thus with the increase of low energy consumption of the vehicle, car buyers may choose to travel longer distances. The rebound effect will offset the reduction of CO2 emissions when using small cars. If the influence of other factors were ignored when the policy was designed, some opposite effect may be produced (Deng and Ma, 2010). Moreover, the effect of policy implementation depends largely on price elasticity, which is difficult for policymakers to grasp (Peters et al., 2008). Consumers tend to adjust the current decisions in the short term, while in long-term they will neglect the impact of policies (Busse et al., 2010). The ultimate goal of implementing an automobile consumption tax is to change the auto market structure in the long term (Knittel, 2011), so policymakers must fully consider the influence of other factors to ensure that the tax can effectively control consumer's behavior over a sustained period of time (Klier and Linn, 2010).

Furthermore, with respect to the automobile consumption tax in China, Zhao (2013) claims that while this tax can better embody the function of environmental protection, it is not conducive to improvements in research and development related technology by domestic automobile manufacturers because its design did not take into account CO2 emissions or taxes on them. Nevertheless, Jiang (2009) compared the production and sales volume of different displacement vehicles before and after the tax rate changes and found that the consumption tax only had an impact on the number of flow cars, not stock cars, yet we show here that it did have an impact on the shares of high and low cylinder cars.

As for empirical research, Xiao and Sun (2012) use a structural model to analyze the demand and supply of vehicles and simulate the automobile consumption tax adjustment. The results show that the consumption tax effectively tilts purchases to cars with smaller displacement and improves the utilization of automotive fuel but, as a byproduct, it may cause loss of social welfare. Similarly, Li and Zhu (2017) find that in the short term, the automobile consumption tax restrained CO2 emissions of automobile production and use by the influences of price effects promoting the technological progress of the automobile industry. In the long term, rebound effect, market effect, production effect, substitution effect and sustained effect lead to negative impact on carbon dioxide emissions. In addition, the implementation of the policy increased sales of small displacement cars while also reducing sales of large displacement cars with 3.0-4.0 liter engines. The policy had no significant impact on cars with 4.0 liter engines. These results align with what we found in this paper as we saw a shift in the market share of large displacement cars.

There is also a body of literature that focuses on the consequences of pollution on human health and how new infrastructure affects air quality. For example, Currie and Walker (2011) estimated that the prenatal exposure to traffic congestion reduce welfare in the United Stated by $557 million per year and Ngo (2017) found evidence that maternal exposure to old buses in New York City is associated with reduction in birth weight and gestational age relative to new buses that abide by new emissions policies. Also, Ngo et al. (2018) investigate the effects of changes in intercontinental air pollution associated with the Chinese New Year, a 7-day national holiday and sandstorms from China on air quality and morbidity in California. They found that heavy sandstorms are associated with a modest increase in acute respiratory disease per capita, representing 0.5–4.6% of average weekly hospitalizations in California while there was no significant effect on morbidity in California caused by the Chinese New Year. Additionally Chen and Whalley (2012) find evidence that green infrastructure has a significant impact on pollution reduction. They quantify the effects of one major type of transportation infrastructure — urban rail transit — on air quality using a sharp discontinuity in ridership on the opening day of a new rail transit system in Taipei. They found that the opening of the Metro reduced air pollution from one key tailpipe pollutant, carbon monoxide, from 15 to 5%.

1.3 Background, Policy Change and Data

China first imposed a sales tax on cars in 1989 in order to exercise some control over ever increasing car sales. On January 1st of 1994, the automobile consumption tax was officially implemented. Due to the small number of car sales, product specialization lag and other factors, it was based solely on car displacement and only divided passenger cars into three groups. In addition to increasing the national financial revenue, the primary purpose of this imposition was to set limits on over consumption of non-necessities.

After twelve years of socio-economic development, the increasing popularity of household automobiles led to increasing problems of resource consumption and environmental pollution. The original passenger vehicle consumption tax was low for large displacement vehicles and lacked regulation on the consumption of passenger cars with large displacement and high-energy consumption. In response to these policy shortcomings, on April 1st of 2006, the Ministry of Finance and the state administration of taxation reformed the passenger vehicle consumption tax. The policy adjustment, which mainly refined the grade of automobile displacement from the original three groups, was the most significant adjustment of the consumption tax since the previous tax reform in 1994. At the same time, it widened the tax rate gap between different emission levels, lowered the car consumption tax rate of automobiles with engine size of 1.0-1.5 liters displacement, and increased the consumption tax rate of all vehicles of 2.0 liters displacement or more. The purpose of this consumption tax reform was to limit the production and sales of passenger cars with high displacement and high fuel consumption while simultaneously encouraging the purchase of small cars.

The adjusted automobile consumption tax had an impact on the purchase behavior of automobile consumers in the two years following its implementation. However, passenger car ownership in China continued to rise sharply along with the demand for gasoline and diesel, resulting in more serious air pollution. As a result, on September 1st, 2008, the Ministry of Finance and the State Administration of Taxation jointly implemented a car consumption tax adjustment. The adjustment of automobile consumption tax aimed to increase the sales tax rate of large displacement passenger cars, control their sales volume, and strengthen the guiding role of consumption tax on automobile consumption by adjusting the tax structure of cars. These changes can be seen in Table 1.1

In order to study this policy change, we will analyze the change in total emissions by cars with high displacement engines (bigger than 3 liters) compared to the change in total emissions by cars with low displacement engines (less than or equal to 3 liters) before and after the policy implementation in 2008. As a pre-policy period we use emissions from 31 provinces in China between 2006 and 2008. This is because in these periods cars with high

Table 1.1: Evolution of Tax Rate on Passenger Cars in China (%)

Displacement	Tax rate -1994	Tax rate (April.1.2006)	Tax rate (Sept.1.2008)
$\leq 1.0L$	3	3	1
$(1.0L \quad 1.5L]$	5	3	3
$(1.5L \quad 2.0L]$	5	5	5
$(2.0L \quad 2.2L]$	5	9	9
$(2.2L \quad 2.5L]$	8	9	9
$(2.5L \quad 3.0L]$	8	12	12
$(3.0L \quad 4.0L]$	8	15	25
$\geq 4.0L$	8	20	40
MLCPC	0	5	5

Source: The authors and Minister of Finance, State Administration and Taxation of China.

displacement engines had a significant increase in the consumption tax while the small cars remain the same. We do not exclude cars that have an engine displacement less than 1 liter, as they represent a small proportion of our sample (around 3-4 % of the total sample of new car registrations in China during the period analyzed). We calculated emissions during the period of 2003 to 2013 and compared this longer sample to the estimation, and found no significant changes for some pollutants. Nevertheless, we prefer the estimation using the pre-policy period as the years after the first tax change given that is easier to motivate that the assumption of parallel trends holds.

Table 1.2: Emission Formulas for Selected Pollutants

Pollutant	**Cylinder capacity**	**Emission Factor (g/km)**
CO	CC < 1,4 l	$9,846 - 0,2867V + 0,0022V^2$
	1,4 l < CC < 2,0 l	$9,617 - 0,245V + 0,0017285V^2$
	CC > 2,0 l	$12,826 - 0,2955V + 0,00177V^2$
NMVOC	CC < 1,4 l	$0,628 - 0,01377V + 8,52E - 05V^2$
	1,4 l < CC < 2,0 l	$0,4494 - 0,00888V + 5,21E - 05V^2$
	CC > 2,0 l	$0,5086 - 0,00723V + 3,3E - 05V^2$
NOX	CC < 1,4 l	$0,5595 - 0,01047V + 10,8E - 05V^2$
	1,4 l < CC < 2,0 l	$0,526 - 0,0085V + 8,54E - 05V^2$
	CC > 2,0 l	$0,666 - 0,009V + 7,55E - 05V^2$

Source: The authors and COPERT 4 Model.

1.3.1 Data

This section gives a detailed explanation on how the emissions from cars with different engine displacements are calculated and the assumptions on which these are based. To estimate the total emissions, we use administrative records of all new car registrations in China which include car characteristics such as the cylinder capacity and number of doors, year and month of registration, as well as city and province as an input in the COPERT model.

The COPERT 4 Model

The COPERT model (Gkatzoflias et al., 2007), funded by the European Environment Agency (EEA), can be used to calculate annual emissions of pollutants and vehicle emission factors. This model, which is widely employed in European countries, uses a large number of reliable experimental data and can be compatible with different national standards and parameter variables. From the COPERT III in 1985 to the current COPERT 4, the information in the model such as standards and vehicle classification are continuously updated which enable the simulation values to be closer to the real world.

Principle of emission factor calculation in COPERT 4 model

The COPERT 4 model considers the pollutants emitted by motor vehicles from three sources: the thermal stabilized engine operation, the cold starting process and fuel evaporation and then calculates the emission factors respectively. (1) In the thermal steady state, the emission factors of different types of engines are only related to the traveling speed of the vehicle; (2) The emissions during the cold starting process is obtained by adding an constant value to the emission at the thermal steady state; (3) The NMVOC of fuel evaporate emissions consists of three components, diurnal emissions, hot soak emissions and running losses, whose emission factors are expressed as a function of the vapor pressure of the fuel and the temperature of the environment.

Table 1.2 shows the calculation formulas of various emission factors of CO, NMVOC and NOx with 3 different cylinder capacity in the thermal stability state. In the cold-start process and the fuel-evaporative emission state, vehicle emission factors of various types of pollutants formula can be found in the literature Gkatzoflias et al. (2007)

The calculation principle

Vehicle emissions are determined by the vehicle's integrated emission factor, average annual mileage, and number of vehicles. Vehicles emit carbon monoxide (CO), nitrogen oxides (NOx) including nitric oxide (NO), non-methane volatile organic compounds (NMVOC), volatile organic compounds (VOC), particulate matters including PM2.5, PM10, and total PM, etc. The common expressions of vehicle emissions of various types of vehicles in COPERT 4 are as follows

$$Q_m = \sum_{jk} (P_{m,i,j,k} \times M_i \times EF_{m,i,j,k}) \tag{1.1}$$

Where m is a certain area, i is one of the types of different vehicles, j is the driving conditions;$P_{m,i,j,k}$ is the vehicle emission in the area m for the type i under driving condition j and emission standard k, measured in 10 million vehicles; M_i is average annual mileage for vehicles category i, measured in kilometers; $EF_{m,i,j,k}$ is an integrated emission factor for vehicles category i under traveling conditions j with emission standard k , measured in gram/kilometer.

We divide the passenger cars into three categories: mini gasoline passenger cars, small gasoline passenger cars, and small diesel passenger cars. The passenger cars are then continuously sub-classified according to emission standards and displacement sizes, and can be subdivided into a maximum of 20 sub-categories. Condition j is divided into three categories: urban areas, suburbs and highways. Emission standards are divided into national 1, national 2, national 3, and national 4 standards for both diesel and gasoline vehicles.

The data of the newly registered passenger cars used in this study comes from the passenger cars database of China Transportation Administration from 2003 to 2013. The data of passenger car ownership in 2002 comes from China Statistics Website. Other relevant data comes from China Automotive Industrial Yearbook, China Meteorological Statistical Yearbook and China Automotive Market Yearbook. The newly registered passenger cars database of China Transportation Administration from 2003 to 2013 is a large-scale original database, and the numbers of newly registered passenger cars of all types are calculated from this database. In addition, another part of the data is obtained from other publications and then used cautiously. In the process of calculation and transformation of the data, in order to ensure the reliability and effectiveness of the results, we maintained a homogeneity across the different sources. Appendix A.1 in this document explains in detail how the COPERT4 model works and the principle to estimate emissions from road conditions.[1]

1.3.2 Descriptive Statistics

Table 1.3 shows some descriptive statistics of the total emissions for eight pollutants we consider. All panels show averages, standard deviations as well as minimum and maximum emissions. The first two panels do so for low and high engine sizes respectively, the third panel is the sum of low and high engine size, while the final panel corresponds to the collapsed information by province and fuel type. The scale of each pollutant is 10 thousand of tons so that, for example, the average emissions of PM2.5 by a low engine sized car is around 1.29 tons or 240 tones for big engine cars. It is also worth noting that some of these emissions are highly variable. For instance, the variation coefficient (standard deviation divided by the mean), which is a measure of relative variability, is very high for the PM2.5 emissions in the high engine size, a value of 1.18 approximately.

Figure 1.1 shows a heat map of pollutant PM2.5, VOC, NOX and NMVOC by province in different years. It is evident that total emissions have been increasing in most provinces, especially in coastal areas such as Shandong, Zhenjiang and Shanghai. Figure 1.2 illustrates the evolution by quarters of the shares of low engine size cars in panel a and of high engine size cars in panel b. The vertical lines represent the moment where the policy tax change happened and the blue dotted line is the mean for the inter periods. Clearly the mean of the share of the low displacement cars was bigger after the two changes, inducing a decrease in the same indicator for high displacement cars. We argue that, by graphical inspection, the response in the consumption was in line with the objective of the policy: to decrease the

[1] Note that since 2000 China started to implement national emission standards equivalent to the European ones, called Euro I-VI. These equivalence allows us to use the COPERT model to estimate emissions for the Chinese automobile fleet. See for example tables A.1 and A.2 in appendix A.1.

share of cars with big engine sizes in the country. We also estimate the DD model for this variable by controlling for other economics characteristics of the province and found evidence towards this argument.

Furthermore, is also important to show how the emissions of each pollutant are behaving during these periods. Figure 1.3 shows a multi-paneled graph with the evolution by year of the eight pollutants we consider. Again, vertical lines represent the years of the policy changes. Values shown on these graphs are the yearly mean in all of the provinces. As expected, the emissions for both large and small displacement cars are increasing overtime but this increase is more notable in certain pollutants. This graph is also important because it informs that the assumption of parallel trends is satisfying for some of the pollutants.

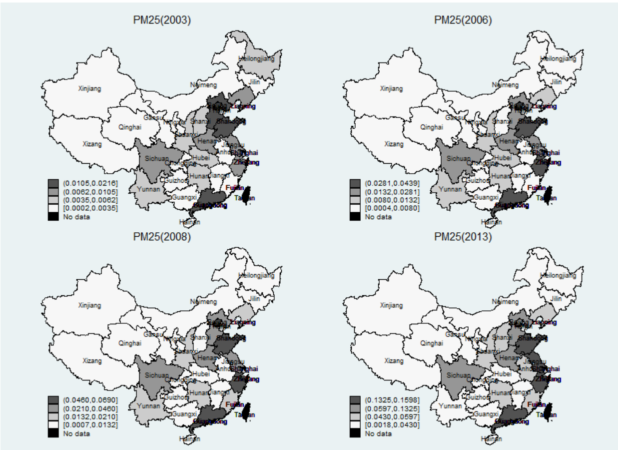
Figure 1.4 is equally important as it shows the log difference in emissions, which is approximately equal to the growth rate of emissions by each pollutant. Even though this rate is positive for all years, it is surprisingly decreasing over time for both high and low engine size cars. We also present estimations in Table 1.5 to interpret the coefficients as differences in percentages changes while carefully acknowledging that changing the unit measures might contaminate the results as parallel trends are likely not satisfying because common trends in logs rules out common trends in levels and vice versa (Angrist and Pischke, 2008).

Table 1.3: Descriptive Statistics by Pollutant

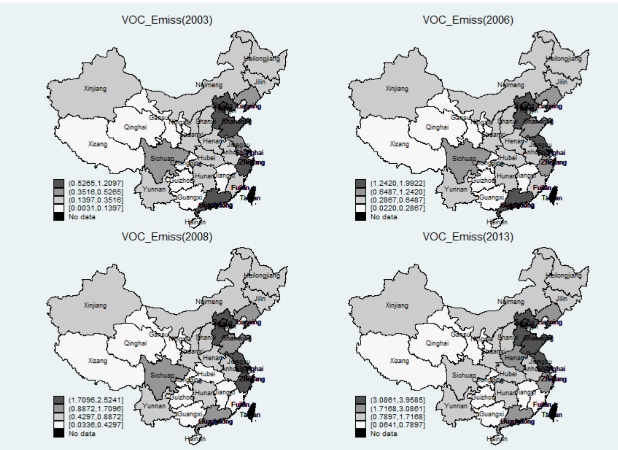
			Low Engine Size		
Variable	Obs	Mean	Std.Dev.	Min	Max
PM25	337	0.000129	0.000124	2.74E-06	0.000706
VOC Emiss	337	0.00416	0.00369	5.21E-05	0.0199
PM10 Emiss	337	0.000223	0.000215	4.69E-06	0.00123
PM exhausts	337	2.23E-05	2.02E-05	5.33E-07	0.000106
NOX Emiss	337	0.00274	0.00232	6.20E-05	0.0118
NO Emiss	337	0.00263	0.00223	5.95E-05	0.0114
NMVOC Emiss	337	0.00386	0.00343	4.91E-05	0.0184
CO Emiss	337	0.0295	0.0276	0.000388	0.152
			High Engine Size		
Variable	Obs	Mean	Std.Dev.	Min	Max
PM25	337	0.024	0.0283	0.000278	0.159
VOC Emiss	337	0.774	0.784	0.0145	3.946
PM10 Emiss	337	0.0414	0.0492	0.000471	0.277
PM exhausts	337	0.00416	0.00456	5.79E-05	0.0247
NOX Emiss	337	0.468	0.474	0.00828	2.507
NO Emiss	337	0.449	0.455	0.00794	2.406
NMVOC Emiss	337	0.722	0.727	0.0136	3.696
CO Emiss	337	5.856	6.49	0.0809	39.48
			Province		
Variable	Obs	Mean	Std.Dev.	Min	Max
PM25	337	0.0241	0.0284	0.000287	0.16
VOC Emiss	337	0.778	0.787	0.0145	3.958
PM10 Emiss	337	0.0416	0.0494	0.000487	0.279
PM exhausts	337	0.00419	0.00457	5.97E-05	0.0248
NOX Emiss	337	0.471	0.476	0.0085	2.519
NO Emiss	337	0.451	0.457	0.00815	2.418
NMVOC Emiss	337	0.725	0.729	0.0136	3.708
CO Emiss	337	5.886	6.512	0.0813	39.58
			China		
Variable	Obs	Mean	Std.Dev.	Min	Max
PM25	11	0.739	0.521	0.172	1.724
VOC Emiss	11	23.94	10.9	8.967	42.27
PM10 Emiss	11	1.276	0.915	0.292	3.015
PM exhausts	11	0.128	0.0739	0.0355	0.257
NOX Emiss	11	14.45	6.485	5.298	24.86
NO Emiss	11	13.86	6.224	5.081	23.85
NMVOC Emiss	11	22.32	9.75	8.637	38.59
CO Emiss	11	181.1	97.63	61.11	345.1

Note: Panel ”Low Engine Size” and ”High Engine Size” are emissions of low and high displacement cars. Panel ”Province” uses all the information form both groups and panel ”China” is the average information collapse by Province and cylinder capacity.

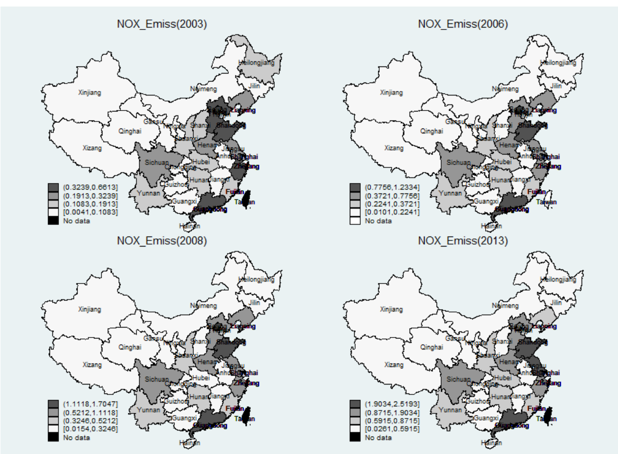
Figure 1.1: Heat map of emissions by selected pollutants



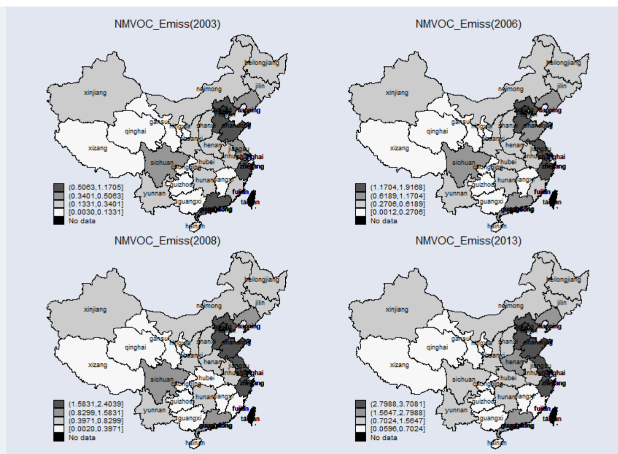
(a) PM2.5



(b) VOC



(c) NOx

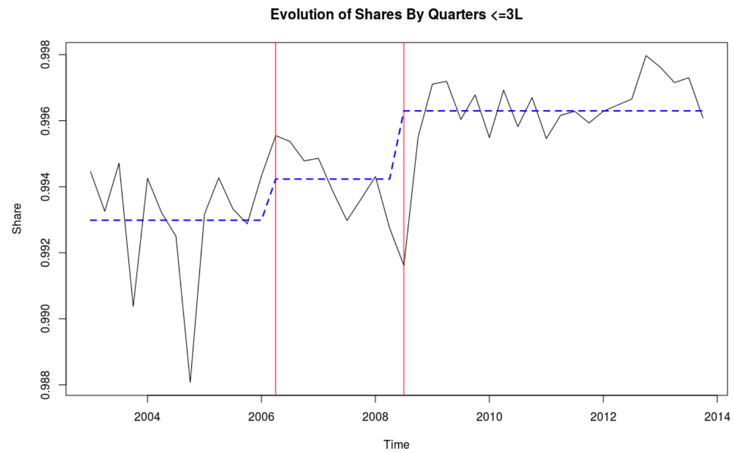


(d) NMVOC

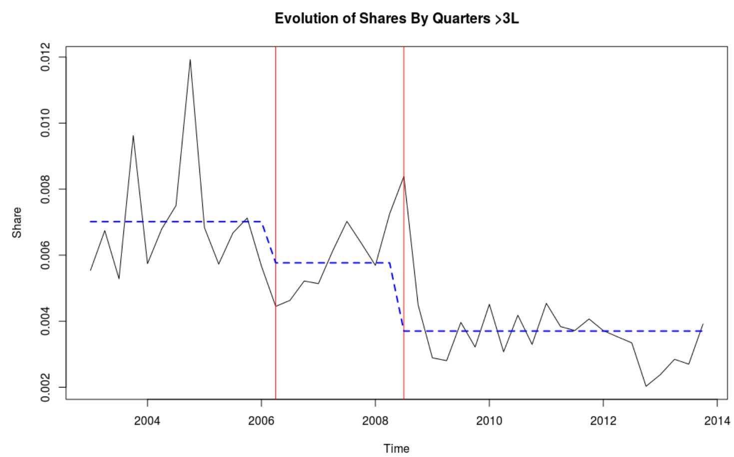
Note: Each graph in each panel represents the emissions by province in 2003, 2006, 2008 and 2013 respectively for PM2.5, VOC, NOX and NMVOC emissions.

Figure 1.2: Evolution of Share for High and Low end Cars

(a) Share less 3L



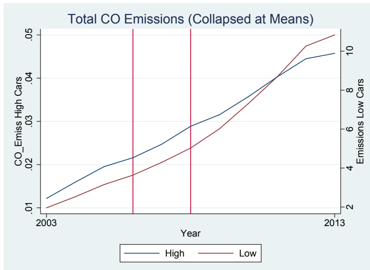
(b) Share bigger 3L



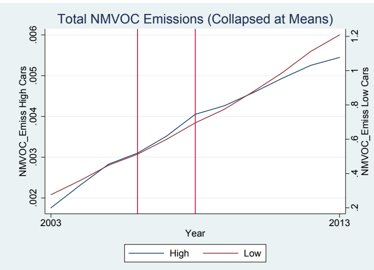
Note: Panel a shows the evolution of the quarterly market shares of the cars with engines size smaller than 3 liters and panel b do so for the cars with engine size bigger than 3 liters. The vertical red lines represents the policy changes (April of 2006 and September of 2008). The dotted blue line represents the average share in the interperiods.

Figure 1.3: Plots of Total Emissions Average By Provinces

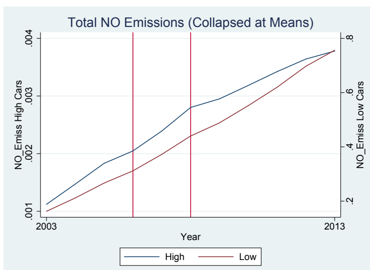
(a) fig 1



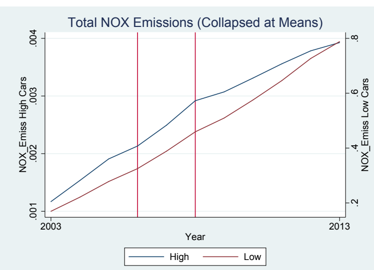
(b) fig 2



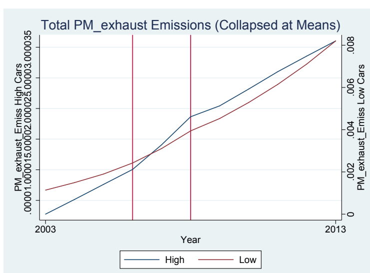
(c) fig 4



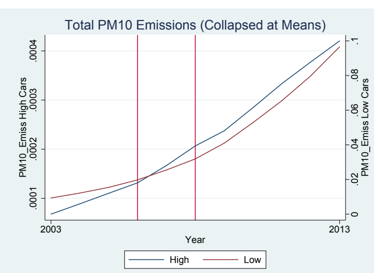
(d) fig 5



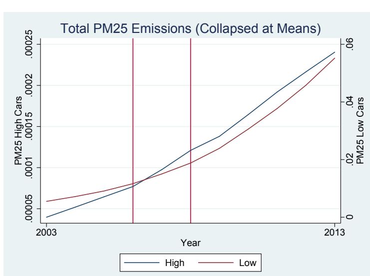
(e) fig 6



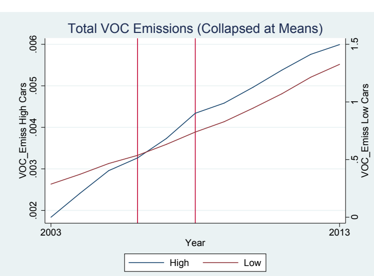
(f) fig 7



(g) fig 8



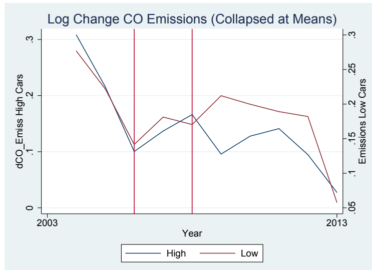
(h) fig 9



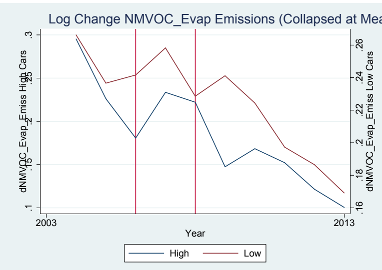
Note: Panels a to h show the evolution of the total emissions of the pollutants CO, NMVOC, NO, NOX, PM, PM10, PM2.5, and VOC respectively for both, high and low cylinder cars; collapse at the means by province. The vertical red lines represents the policy changes (April of 2006 and September of 2008).

Figure 1.4: Plots of Log Differences

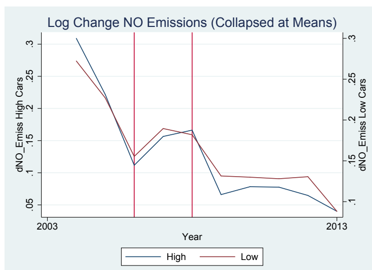
(a) fig 1



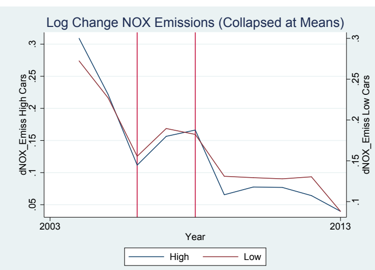
(b) fig 2



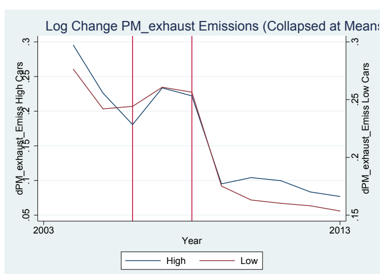
(c) fig 4



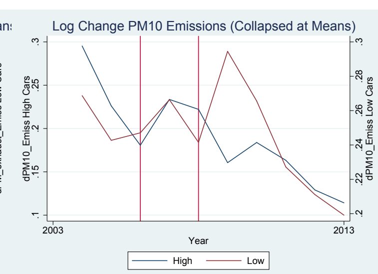
(d) fig 5



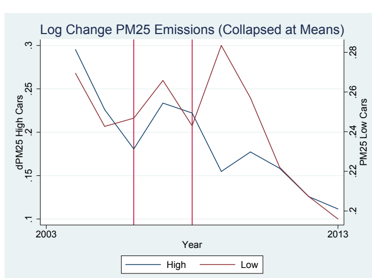
(e) fig 6



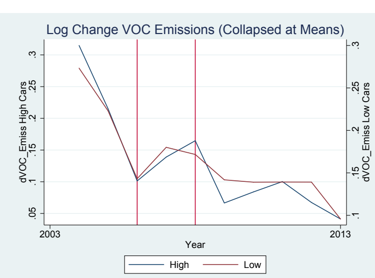
(f) fig 7



(g) fig 8



(h) fig 9



Note: Panels a to h show the evolution of the log change in the total emissions of the pollutants CO, NMVOC, NO, NOX, PM, PM10, PM2.5, and VOC respectively for both, high and low cylinder cars; collapse at the means by province. The vertical red lines represents the policy changes (April of 2006 and September of 2008).

1.4 Statistical Analysis and Results

In this section we introduce our identification strategy to estimate the total effect of the consumption tax policy on the total emissions by big cars. Likewise, we present a series of robustness checks to strengthen the core findings of this paper while checking for parallel trends.

1.4.1 Econometric Setup

We estimate Difference-in-Difference (DD) models to calculate the change in total emissions after the policy. The general formulation is:

$$y_{pft} = \alpha + \lambda_t + \gamma_1 Policy_t + \gamma_2 Size_f + \gamma_3 Policy_t * Size_f + \mathbf{X}_{tp}\beta + \varepsilon_{pft} \tag{1.2}$$

Where y_{pft} is the total emission by one of the eight pollutants in the province p by engine size f in year t. $Policy_t$ is an indicator variable that takes the value of 1 after 2008 and $Size_f$ indicates if the emission is coming from a high cylinder car. λ_t is a linear time trend variable and $\mathbf{X}_{tp}$ is a set of controls that includes unemployment rate by province, GDP per-capita by province and a full set of province indicators, ε_{pft} is an econometric error term.

The coefficient of the interaction term, γ_3 is the value of interest in this study. It is the DD estimator and that takes the difference in emissions between high and low cylinder cars from the difference between the "before" and "after" periods. This is:

$$\gamma_3 = \{E\left[y_{pft}|f = High, t = After, \mathbf{X}\right] - E\left[y_{pft}|f = High, t = Before, \mathbf{X}\right]\} - \\ \{E\left[y_{pft}|f = Low, t = After, \mathbf{X}\right] - E\left[y_{pft}|f = Low, t = Before, \mathbf{X}\right]\}$$

This is a very standard DD set up that allows us to estimate the coefficient of interest by controlling for different variables while easily calculating the standard errors. We would expect that γ_3 would reflect a negative relationship between the emissions and the implementation of the policy if people substitute high cylinder cars with smaller ones.

The intuition behind our estimation strategy is simple. The reason why pollution could change after the adjustment of this tax is through a behavioral response that individuals would face as the high cylinder cars are relatively more expensive than the small ones; thus a higher tax should change the market shares of these cars, decreasing their pollution emissions. By flexibly controlling for nonlinearities in pollution from other factors and using a full set of time dummies, we are able to isolate the change in pollution solely due to the change in the tax system. Our coefficient of interest, γ_3 will estimate the reduced form effect of the tax on air quality and it will strongly depend on the behavioral response of consumers[2]. The next section shows the results of these estimations.

1.4.2 Inference

In causal inference studies with changes at the regional level (i.e, state, municipalities, etc.), researchers typically conduct inference based on standard errors clustered at the regional level to account for correlation in the policy variable (Jones et al., 2015). In this exercise we use robust cluster standard errors to conduct inference. In deciding the cluster, accounting for the correlation in treatments status due to assignment is an important consideration in choosing an appropriate level of clustering standard errors (Abadie et al., 2017).

Conventional methods have been proved to be wrong when there are few clusters (Bertrand et al., 2004), in this case, we cluster the standard errors at the province level. MacKinnon and Webb (2017a,b) showed that conventional cluster-adjusted standard errors cause rejection rates twice what they should be. Thus, we use a second approach by conducting inferences that account for clustering using the wild bootstrap method and a six-point distribution (Webb, 2013). We report p-values for both approaches: the conventional robust-clustering method, and the wild bootstrap in appendix A.2.

[2]The behavioral response not only affects the market shares but also other key variables. For instance, the speed of the cars on the roads, and the changes in the composition of the roads. More cars are more likely to create more traffic congestion which affects average speeds; small engine cars are slower than high cylinder cars which could also affect the average speed. If there are more small cars, the roads needed for them to circulates change as well; for example, less highways are needed and more rural roads are constructed, etc. We believe that the key identification comes from the fact that the market shares will change due to the tax and so will the emissions by these cars. We also show evidence that other policies that restrict the circulation of cars, implemented in the same time, do not affect the core of our results.

1.4.3 Effect on Total Shares

To analyze the effect of the change in the consumption tax on the total share of big and small cylinder cars we use quarterly shares from 2003 to 2012, and we estimate equation 1.2 using as outcome variable the market share of each type of car with no other covariables. These shares are not province specific, rather the total national share of cars with engine sizes bigger and smaller than 3 liters. Table 1.4 shows this estimation.

Table 1.4: Effect on the Total Share of Big Engine Size

Shares	(I)	(II)
γ_3	-0.0015	-0.6445
Std. Err.	(0.0001)	(0.0924)
Observations	88	88

Note: Robust standard errors are in parenthesis. Each row is the estimate of γ_3. Column (I) shows the estimations for the shares in levels while column (II) does so for the logarithm of the share.

There is a significant negative effect on the share for small and big cylinder cars. Column (I) shows the effect for the shares in its levels, while column (II) does so for the logarithm of the share. These results show evidence of a substitution effect from big to small cars after the policy implementation[3].

1.4.4 Results

Table 1.5 shows the estimations from equation 1.2. Each row is the estimate of γ_3 for one of the pollutants in this study. Columns (I) and (II) correspond to a different regression estimate that includes a province specific linear trend, full set of year controls plus a full set of province dummies augmented with economic condition variables like GDP per capita and unemployment rates. The estimates in the first column are robust to the inclusion of

[3] For the next set of results to hold valid, the price elasticity of small engine cars cannot be too large, otherwise the sales of small engine cars will increase so much so that emissions will increase. By showing the effect on shares we show evidence that there is effectively a substitution effect. Unfortunately, we do not have price information.

province controls or the choice of linear trends or non-linear ones[4]. All the coefficients are significant at a 1% level and they are also negative, which indicate that the change in the tax structure decreased the emissions of the high cylinder cars.

Table 1.5: Effect in Total Emissions

Pollutant	*(I)*	*(II)*	*(III)*
VOC	-0.2423	-0.0910	-0.2300
	(0.0413)	(0.0173)	(0.0399)
PM10	-0.0189	-0.1193	-0.0182
	(0.0030)	(0.0431)	(0.0030)
PM	-0.0018	-0.0875	-0.0017
	(0.0003)	(0.0416)	(0.0003)
NOX	-0.1510	-0.0651	-0.1453
	(0.0261)	(0.0345)	(0.0260)
NO	-0.1449	-0.0646	-0.1394
	(0.0251)	(0.0345)	(0.0249)
NMVOC	-0.2159	-0.0914	-0.2046
	(0.0374)	(0.0167)	(0.0360)
CO	-2.0783	-0.1177	-1.9584
	(0.3649)	(0.0200)	(0.3500)
PM25	-0.0109	-0.1163	-0.0105
	(0.0018)	(0.0430)	(0.0017)
Observations	*304*	*304*	*294*

Note: Clustered standard errors by province are in parenthesis. Each row is the estimate of γ_3, every column corresponds to a different regression estimate that includes a province specific linear trend or a full set of year controls, and a full set of province dummies. All the regressions include economic condition variables like GDP per capita and unemployment rates. Column (I) use the total emissions in levels, Column (II) uses the logarithm, and Column (III) excludes the information from Beijing in its levels.

The results from Table 1.5 contain two central findings. First, the decrease in the emissions by high cylinder cars is robust with the inclusion of any type of trend and independent as well of the inclusion of province control. Second, the highest change was evident in the

[4]Putting in time dummies allows for any kind of trend, of which a linear trend is a special case and the reason why both cannot be in the same regression. Likewise, controlling for province specific trends allow us to control for increases in highway mileage, and high-speed train railways in each province.

emissions of CO and NMVOC. Given that health consequences of carbon monoxide are quite significant, this change is notable.

As these raw changes are difficult to interpret, column (II) of table 1.5 presents the changes in the log of emissions so the results can be seen as differences in percentage changes. Thus, for CO, the emissions of high cylinder cars, after the new tax system, were 11.7% lower than the low cylinder ones. It is also important to note that emissions from PM10 and PM25 were also around 11% lower for the treated group. On the other hand, the smallest change was in NO emissions, which amount to a 6% decrease, something that did not appear in the table using the variables in their levels.

These results point to a very convincing story where the change in the emissions by high cylinder cars were significantly lower than the small engine cars. It is therefore important to show that the baseline results are robust to other policies potentially impacting emissions which were implemented at the same time. The next section overviews this.

1.4.5 Robustness Checks

Beijing is not Driving the Results

Driving restrictions are used in numerous cities around the world to reduce pollution and congestion and during the same period, Beijing, the biggest and most important city in China, implemented a series of policies that restrict the circulation of cars by the plate number. On July 20th, 2008, the restriction, based on license plate numbers, initially prevented driving every other day and then decreased to one day per week. Viard and Fu (2015) show empirical evidence of this driving restrictions' effect on pollution and economic activity. They found that the restrictions significantly reduce particulate matter and found little evidence of inter-temporal substitution of driving.

Here we want to analyze whether this restriction could be driving our results. For this end, we re-estimate our baseline model excluding the information from Beijing and show the results in column (III) of table 1.5.

These estimates are very encouraging. Even though the results are slightly less pronounced than in columns (I) and (II), the same story applies as the coefficient of the estimations remain unchanged and statistically significant. This leads us to conclude that it is very unlikely that the restriction on circulation in Beijing is the influential factor driving our results. The fact that Viard and Fu (2015) found little evidence of inter-temporal substitution of driving, while simultaneously finding a significant reduction in particulate matter, lines up with the results of this paper whilst also providing evidence for the hypothesis that the change in the tax system for high cylinder cars reduced total emissions, not only for particulate matter (PM) but also for other pollutants emitted by cars.

Including Different Trends by Fuel Type

The key assumption that allows us to use the low engine size group as a correct control group for the preexisting differences between the treated and the control, is that the temporal trends of the pollution variables between the pre and post policy periods are the same between the two groups. In other words, the pollution variables evolve in time in the same manner in both groups. In existing literature this is known as the parallel trend assumption and is important for identification. The first way to test for this trend is by graphic inspection of the evolution in time of the pollution information for both groups, which can be seen in Figure 1.3. For pollutants like NO, NOX and CO, it is evident that this assumption is satisfactory but less clear for other pollutants by a simple graphic inspection.

In order to test for parallel trends we augment equation 1.2 by including fuel specific trends in the equation. This allows treatment and control cars to follow different trends in a potentially revealing way. As a rule, DD estimation with fuel-specific trends is likely to be more robust and convincing when the pretreatment data establishes a clear trend that can be extrapolated into the post-treament period (Angrist and Pischke, 2008). There is a similar specification to the one used in Besley and Burgess (2004). We estimate the following equation:

$$y_{pft} = \mu_L t + \mu_H t + \gamma_1 Policy_t + \gamma_2 Size_f + \gamma_3 Policy_t * Size_f + \mathbf{X}_{tp}\beta + \varepsilon_{pft} \tag{1.3}$$

where μ_L and μ_H are low engine size (less than 3 liters) and high engine size (bigger than

3 liters) trend coefficient multiplying a time trend variable. If our estimations do not change after including these specific trends, we are allowed to assume that parallel trends is not an issue here. Table 1.6 shows the estimations when including these specific trends. Each column represents a estimation that add trends by fuel and a combination of time controls and province dummies. It is important to notice that for most of our specifications and pollutants, the coefficient signs remain unchanged as well as statistically significant.

In table 1.7 we follow a similar exercise but we exclude the information from Beijing to control as well for other kinds of policies implemented during the same time period. The core findings remain unchanged[5].

Effect on the Air Pollution Index

To compare the results obtained using the COPERT data, we obtain information from the Mainland China Urban Air Quality History database[6] using an Air Pollution Index (API). This API is used to determine the concentration of different pollutants to give an approximation of the air quality in a given region. The pollutants included in the API are the daily average of SO2, NO, and PM10, as well as the hourly average of CO and O3. This data on pollutants is then averaged into daily, monthly, quarterly and yearly levels. We use the information aggregated at the province-year level to compare the main results using the COPERT data. The API is a linear interpolation from the concentration levels of the five pollutants; table A.7 in appendix A.3 shows the different classification for these pollutants. Higher levels on the API index imply a lower air quality with a range from 0 to 300; these conditions are categorized in table A.6 of appendix A.3.

We use this information to estimate the following equation:

[5] Because the policy change was around the same period of time of the world economic downturn of 2007, a cooling down of the Chinese economy might also decrease the consumption of bigger, more expensive cars. Thus reducing the share of big cylinder cars. We argue this is not the case as the GDP growth of China slowed down during the periods of 2007 to 2009 but recovered itself in the subsequent years. Panel b of figure 1.2 shows that immediately after the policy implementation, the share of cars with engine size bigger than 3 liters decreased and stayed in the same level thereafter, suggesting that this effect was not driven by a possible deceleration of the Chinese economy.

[6] This information is publicly available and can be download from https://www.gracecode.com/aqi.html. The information covers the period from June of 2000 to February of 2015 for all provinces in China.

Table 1.6: Effect on the Total emissions Different Engine Trends

Pollutant	*(I)*	*(II)*	*(III)*	*(IV)*
VOC	-0.1159	-0.0980	-0.0087	-0.0087
	(0.0406)	(0.0333)	(0.0122)	(0.0115)
PM10	-0.0132	-0.0059	0.0041	0.0041
	(0.0027)	(0.0026)	(0.0009)	(0.0009)
PM	-0.0011	-0.0008	-0.0002	-0.0002
	(0.0003)	(0.0002)	(0.0001)	(0.0001)
NOX	-0.0739	-0.0692	-0.0168	-0.0168
	(0.0247)	(0.0196)	(0.0081)	(0.0077)
NO	-0.0709	-0.0661	-0.0157	-0.0157
	(0.0237)	(0.0188)	(0.0077)	(0.0073)
NMVOC	-0.0971	-0.0889	-0.0115	-0.0115
	(0.0373)	(0.0300)	(0.0112)	(0.0106)
CO	-1.1731	-0.6128	0.3868	0.3868
	(0.3547)	(0.3205)	(0.1159)	(0.1099)
PM25	-0.0075	-0.0035	0.0021	0.0021
	(0.0016)	(0.0015)	(0.0005)	(0.0005)
Trend by Engine	*Yes*	*Yes*	*Yes*	*Yes*
Time Control	*No*	*No*	*Yes*	*Yes*
Province Control	*No*	*Yes*	*Yes*	*No*
Observations	*304*	*304*	304	*304*

Note: Clustered standard errors by province are in parenthesis. Each row is the estimate of γ_3, and every column corresponds to a different regression estimate that includes a specific linear trend by engine size or a full set of year controls or a full set of province dummies. All the regressions include economic condition variables like GDP per capita and unemployment rates.

Table 1.7: Effect on the Total emissions Different Engine Trends (No Beijing)

Pollutant	*(I)*	*(II)*	*(III)*	*(IV)*
VOC	-0.1143	-0.1011	-0.0084	-0.0084
	(0.0413)	(0.0335)	(0.0117)	(0.0111)
PM10	-0.0116	-0.0060	0.0039	0.0039
	(0.0025)	(0.0027)	(0.0009)	(0.0009)
PM	-0.0009	-0.0008	-0.0002	-0.0002
	(0.0003)	(0.0002)	(0.0001)	(0.0001)
NOX	-0.0586	-0.0700	-0.0162	-0.0162
	(0.0258)	(0.0201)	(0.0080)	(0.0076)
NO	-0.0562	-0.0670	-0.0151	-0.0151
	(0.0248)	(0.0192)	(0.0076)	(0.0072)
NMVOC	-0.0976	-0.0918	-0.0110	-0.0110
	(0.0382)	(0.0301)	(0.0108)	(0.0102)
CO	-1.1879	-0.6535	0.3639	0.3639
	(0.3538)	(0.3212)	(0.1117)	(0.1059)
PM25	-0.0066	-0.0036	0.0020	0.0020
	(0.0015)	(0.0015)	(0.0005)	(0.0005)
Trend by Engine	*Yes*	*Yes*	*Yes*	*Yes*
Time Control	*No*	*No*	*yes*	*Yes*
Province Control	*No*	*Yes*	*Yes*	*No*
Observations	*294*	*294*	*294*	*294*

Note: Clustered standard errors by province are in parenthesis. Each row is the estimate of γ_3, and every column corresponds to a different regression estimate that includes a specific linear trend by engine size or a full set of year controls or a full set of province dummies. All the regressions include economic condition variables like GDP per capita and unemployment rates and excludes the information for Beijing.

$$API_{pt} = \alpha + \gamma_1 Policy_t + \mathbf{X}_{pt}\beta + \varepsilon_{pt} \tag{1.4}$$

where the covariables have the same definition as before. Our sample ranges from 2003 to 2013 with 2008 as the change year. Note that this is not a difference-in-difference estimation, as we cannot separate the emissions from low and big cars; in fact that is the advantage of using the COPERT information, as we can identify and calculate the expected emissions for different types of engine sizes. γ_1 shows the difference in the mean of the API before and after the implementation of the tax policy. Table ?? shows the estimations.

Table 1.8: Effect on the Air Pollution Index

API	(I)	(II)	(III)	(IV)
γ_1	.3877	-3.4606	-12.3400	-21.3932
Std. Err.	(2.0808)	(3.2460)	(2.0040)	(4.4586)
GDP and UR	No	Yes	Yes	Yes
Province Controls	No	No	Yes	Yes
Province Trend	No	No	No	Yes
Observations	326	326	326	326
R-squared	0.0068	0.0131	0.3683	0.3861

Note: Clustered standard errors by province are in parenthesis. The estimations correspond to γ_1 from equation 1.4 for the period 2003-2013, and every column corresponds to a different regression estimate that includes no controls in column (I), Province economic activity controls like GDP and unemployment rate in column (II), province dummies in column (III), and province specific trends in column (IV).

When no controls are included, the mean of the API from before and after the policy increased by around 0.4 points, indicating minimal changes in the air quality though this result is not statistically significant; however, when controls for economic activities for each province were included the estimated effect changes sign with not statistical significance results. When province dummies were included, the magnitude of the difference increased by almost 4 times more than when GDP and unemployment rate by provinces were the only controls included. Finally, column (IV) adds a province specific trend in order to account for changes in railway systems and highway mileage that can possible effect air quality. The last exercise almost double the estimation. The estimations in column (III) and (IV) imply that the average value of the Air Quality Index is lower after the policy when adding a full set of province controls and linear trends. It is important to remark that this is not a causal estimation, as we cannot separate the effects by different engine size. However, these results give a general view of what is happening with the air quality before and after the implementation of the tax policy. When Using COPERT data we found that the total emissions by high cylinder cars was smaller when compared to the controls, a consistent result when using the air quality information.

1.4.6 Using a Different Control Group

There is some concern regarding the validity of the control group when the treatment affects the control group as well (see for example Heckman comments on Eissa (1996)). Table 1.4 shows a small but significant effect on the total shares of cars with engine size lower than 3 liters, as it is likely that individuals most affected by the tax are switching from buying big cars to buying smaller cars. To check the robustness of our estimates to this possibility, we repeat the exercise using cars with an engine size of less than 2 liters as a control group. Based on the assumption that individuals who would have bought a large car - but will not because of the tax - now are likely to buy a car as close in size to the 3 liter cut off as possible, a better control group would be cars smaller than 2 liters. Table 1.9 shows the estimations equivalent to 1.5 using as control group the emissions of cars with engine size lower than 2 liters.

Results in table 1.9 show exactly the same trend than when we use the emissions of cars with engine size less than 3 liters as a control group. Column (I) shows the estimates for the level of emissions, column (II) uses as outcome the logarithm of emissions and column (III) uses the level of emissions omitting the information from Beijing. All columns in the estimation show the same signs as in table 1.5, with a particular increase in magnitude of the coefficient for Particulate Matter 1.0, 2.5, and Carbon Monoxide in column (I) and (II). From the logarithm estimates, these pollutants show a decrease in around 13% in total emissions by cars with big engine size with respect to cars with engine size lower than 2 liters, an increase of around 2 percentage points in magnitude when using the initial control group.

Table 1.9: Effect on Total Emissions Using 2 Liters as Control

Pollutant	*(I)*	*(II)*	*(III)*
VOC	-0.2151	-0.1048	-0.2047
	(0.0363)	(0.0186)	(0.0354)
PM10	-0.0163	-0.1383	-0.0157
	(0.0025)	(0.0462)	(0.0026)
PM	-0.0015	-0.0932	-0.0015
	(0.0002)	(0.0447)	(0.0002)
NOX	-0.1301	-0.0737	-0.1254
	(0.0219)	(0.0359)	(0.0219)
NO	-0.1248	-0.0739	-0.1203
	(0.0210)	(0.0359)	(0.0210)
NMVOC	-0.1924	-0.1053	-0.1829
	(0.0329)	(0.0179)	(0.0320)
CO	-1.8642	-0.1345	-1.7620
	(0.3274)	(0.0212)	(0.3176)
PM25	-0.0094	-0.1347	-0.0090
	(0.0015)	(0.0461)	(0.0015)
Observations	*304*	*304*	*294*

Note: Clustered standard errors by province are in parenthesis. Each row is the estimate of γ_3, every column corresponds to a different regression estimate that includes a province specific linear trend or a full set of year controls, and a full set of province dummies. All the regressions include economic condition variables like GDP per capita and unemployment rates. Column (I) use the total emissions in levels, Column (II) uses the logarithm, and Column (III) excludes the information from Beijing in its levels.

These estimates are remarkably consistent for all the sample restrictions and test we have conducted here. Appendix A.4 shows the table for the rest of estimations.

1.5 Concluding Remarks

Using information about emissions of pollutants gathered from the COPERT 4 model developed by the European Environmental Agency, we found evidence that this tax policy, that increased the consumption tax that high cylinder cars have to pay, reduced the emissions of these cars compared to small ones in all of the eight pollutants considered. These results are robust to the exclusion of large provinces that implemented other policies to reduce car emissions and to the inclusion of engine specific time trends.

Our results showed that Particulate Matter and Carbon Monoxide emissions decreased by around 11%, while Volatile Compound and Nitric Oxide decreased by roughly 7%, when using the emissions of cars with engine size smaller than 3 liters, whereas these estimates increase to 13% for CO and PM while for NOX the estimates remains in around 7% when using the emissions of cars with engine size lower than 2 liter. These results are robust to the inclusion of province fixed effects, economic conditions and specific trends by province, different engine size trends as well as contamination by other possible policies.

We extend our results by estimating the effect on an Air Pollution Index. This index does not have specific information on the total emissions by different cylinder size and it includes combined emissions from multiple sources, such as industry and transportation. However, we provide enough evidence that the total air quality improved after the implementation of this tax policy, which effectively strengthens our results. This last set of estimations is robust to the inclusion of province specific variables like GDP, Unemployment rate, specific trends, and fixed effects.

One important extension for this document is to exploit the micro information contained in the registry of cars. Thus far we have used it to calculate the number of cars on the road and total pollution. However, this information can be used to estimate structural models of demand for differentiated goods in the spirit of Berry et al. (1995) and Li et al. (2015). These types of models would allow the researcher to compute counterfactual analysis of the impact of the policy on total pollution by estimating a supply and demand system of the automobile industry.

Chapter 2

The Effect Of The Affordable Child Care Policy And Occupation Concentration.

Andres Arcila

2.1 Introduction

Gender equality is at the forefront of the policy agenda in many OECD countries. Since the 1960s, much progress has been made to ensure women have the same access to the labour market as men do. However, the fact that parenthood imposes a steep cost on workers who must care for young children continues to be an obstacle in the struggle for equality. Women often leave the labour force for extended periods to attend to the well-being of their offspring, resulting in substantial losses in human capital, employment opportunities, and the subsequent increase in gender inequality. One was to offset the effects of parenthood is to use childcare policies to help families afford the cost of caring for young children. According to the neoclassical model of labour supply, lower costs of child rearing should reduce the reservation wage of women, increasing their incentives to participate in the labour force. I consider here that lower childcare cost might also enable parents to change their occupation by allowing longer job search, increased time commitment to labour market, or further investment in human capital. This paper aims to estimate the effect of an affordable-childcare policy implemented in Quebec in 1997 on the average market share of employment in given occupations. In particular, I ask whether the concentration of employment in different occupations in Quebec, as a result of this policy, changed when compare to the rest of Canada.

Over the last two decades there has been a sharp increase in labour supply of women in North America. The share of working women with kids younger than the age 6 rose from 34 percent in 1976 to 56 percent in 2004 in the United States while in Canada it went from 31 to 67 percent Baker et al. (2008). This did put pressure on the demand for childcare in these countries, making it a heated political discussion during election years.The need for an affordable childcare policy became an important issue in many states and provinces in the US and Canada.

In 1997, the province of Quebec, introduced a subsidy to provide affordable childcare for children under 5. The core of the policy was to provide regulated childcare centres for children aged 0-4 in Quebec at a cost of $5.00 per day to parents. There is substantial evidence that the policy increased the labour force participation of women, but no research has been done about whether the policy affected the concentration of workers in different occupations after the policy.

Several studies have looked at the effects of this policy on the labour supply. The most relevant analog study was conducted by Baker et al. (2008) on the effect of childcare on maternal labour supply and family well-being as well as on the cognitive and behavioural impact on children. They found strong evidence of an increase in the labour supply of married women and significant changes in the cognitive scores of their children following the implementation of the policy. More recently, the same authors investigate the long term effects of the policy on cognitive outcomes in children and the effect on families Baker et al. (2015). Lefebvre and Merrigan (2008) also found strong evidence of an increase in women labour supply after the implementation of this policy. Further to this study, Lefebvre et al. (2009) estimate the dynamic labour supply effects of the program; and find that the policy had a long-term labour supply effects on mother who benefited from the program when their child was less than 6.

Another branch of this literature has focused on verifying the distributional impacts of this policy on the cognitive outcomes of the children. For example, Kottelenberg and Lehrer (2017a) explore this same policy in relation to gender gaps in academic achievement and find that access to universal childcare did not result in a statistically significant difference in children's outcomes based on gender. In a similar study Kottelenberg and Lehrer (2013) find a substantial heterogeneity in program impacts that occur in response to the Quebec policies and indicate that most of the negative impacts reported in earlier research are driven by children from families who only attended childcare in response to the implementation of this policy. Moreover, Kottelenberg and Lehrer (2017b) uncovers substantial policy relevant heterogeneity in the estimated effect of access to subsidized childcare across two developmental score distributions for children from two-parent families and in policy impacts based on children´s age (Kottelenberg and Lehrer, 2014) . Specifically children who gain access to subsidized childcare at earlier ages experience significantly larger negative impacts on developmental scores, health and behavioural outcomes.

Finally, Haeck et al. (2015) offer an overview of the impact of the program. They show strong evidence that implementing full-day kindergarten alone was not enough to increase maternal labour force participation and weeks worked. However, when this policy was combined with a low-fee daycare program, it did cause lasting increases in maternal labour force participation. Their results on cognitive development suggest the reform did not improve school readiness and may even have had negative impacts on children from low-income families.

Schirle (2015) explores the effect of the Universal Childcare Benefit introduced by the federal government in Canada, a benefit that provides a family with $100 per month per child under the age of 6. Using a similar methodology, she finds that the Canadian Universal Child Care Benefit has a significant negative income effects on the labour supply of married individuals. In a follow up study, Koebel and Schirle (2016) examined the effects of the Universal Child Care Benefit on the labour supply of mothers. They found that the benefit has a significant negative effect on the labour supply of legally married mothers, reducing their likelihood of participation in the labour force.

The effects of childcare policies have also been studied in other countries. For example, Havnes and Mogstad (2011) examined the expansion of subsidized childcare in Norway and its effects on the maternal employment rate. They find that the new subsidize childcare instead of increasing mother's labour supply, it mostly crowded out informal care arrangements, implying a significant net cost of child care subsidies. Bauernschuster and Schlotter (2015) investigated the introduction of a legal claim to a child´s spot in kindergarten in Germany and resulted in a marked increase in kindergarten attendance of three-years old. Their results suggests positive effects of public childcare on maternal employment.

In this paper I estimate the effect that the affordable childcare policy in Quebec had on the share of employment in different types of occupations. To achieve this, I will use a Difference-in-Difference-Differences (DDD) methodology to estimate the effect of the policy on the share of employment in each occupations. The DDD method produces causal estimates by comparing the outcomes of parents in Quebec (treated group) relative to non parents and parents in other provinces provinces (control) that were affected differently by the childcare policy.

To see whether the childcare policy influenced the concentration of workers into certain types of occupations, I assign to each worker the employment share of their occupation and estimate the impact of the policy on the average share of employment of a given group of occupations[1]. I am interested in whether the policy changed concentration on female (male) dominated occupations, and in gender balanced occupations. I will also consider whether the policy increased the concentration of workers in "good" jobs, that is jobs requiring high levels of cognitive or social skills, or highly paid jobs. For this part of the analysis I classify occupations according to an index of the skills required in each occupation. The skill index is constructed similarly to others in the literature, using principal component analysis to reduce the many attributes of jobs included in the O*Net database to a single index measuring the amount of a given skill required for a particular job. I will consider three skills: cognitive, social and physical.

Results show that, even though there was an increase in the labour force participation of women in Quebec compared to the rest of Canada, the change in the share of employment in all of the occupations was negative when using the finer 4-digit SOC classification, which

[1]Intuitively, one could think of a random utility model where homogeneous individuals chose occupations based on their characteristics. Under certain assumptions (Berry et al., 1995; Petrin, 2002) workers choices could be represented by the share of total employment of the occupation.

suggests a decrease in the concentration of occupations. I also found evidence that concentration in female dominated and gender balanced occupations increased, while concentration in male dominated occupations decreased. Finally, I do not find evidence that this policy increased the concentration of highly paid occupations or cognitive intensive occupations. To the extend that this may reflect occupational changes away from these occupations, it does not appear that the affordable childcare policy helped to attract workers to better jobs.

An outline of the paper follows. In the next section 2.2 I explain the data chosen for the study as well as, the policy change and the empirical strategy. In section 3.5 the key results are shown and section 3.6 gives a brief conclusion.

2.2 Data and Empirical Specification

2.2.1 Data

I use the confidential microfiles of the Labour Force Survey (LFS) from 1994 to 2003. The LFS is a rotating panel that is conducted monthly to produce unbiased estimate of various statistics including the unemployment rate. The data uses a stratified multistage probability sample design and interviews approximately 59,000 Canadian households each month and each individual is follow for six month.

The survey includes a rich variety of variables. It contains information about the characteristics of the job, such as, coverage by a union agreement, part-time or full-time employment, the reasons why the individual chooses part-time hours, etc. I do not exploit the panel structure of the survey as it is very unlikely that the share of occupations change dramatically during the period the individual is surveyed. For this reason, I only use the information on the individual when it appears for the first time in the survey. I restrict the sample to individuals aged 19 to 55 that are in the labour market, that is, that reported to be employed or looking for a job and not self-employed during the survey. Table xxx[2] shows some summary statistics of the information.

There are several sample restrictions in the estimations. The main focus will be on the

[2] I do not present summary statistics at this stage because of the RDC vetting process

effect of the policy on women in two parent families but also estimations with single parents will be conducted to check the results.

2.2.2 The Policy Change

In 1997, the Province of Quebec, the second most populous in Canada, introduced a set of new family policies which included a highly subsidized childcare benefit. These policies were the result of a extensive public discussion Jenson (2004) and they share common characteristics with childcare policies in Europe Tougas (2002). The core of the policy was to provide regulated child care centres to kids aged 0-4 in Quebec at a parental contribution of $5.00 per day Baker et al. (2008)[3]. The policy was gradually implemented, starting in 1997 with children aged 4 becoming eligible for the program. Children aged 3 were included by September of 1998, children aged 2 years by 1999, and finally, infants 1 year and younger were eligible by 2000. The Quebec Family Policy also increased parental leave benefits and provided families with a standard child allowance based on income, family type (single parent, two parent), and number of children.

2.2.3 Empirical Specification

I estimate a Difference-In-Difference-in-Difference model comparing the outcome of eligible parents in Quebec and in the rest of Canada during the time of the policy. I denote the period between 1994-1997 as "before the policy reform" and the period between 2000-2003 as "post reform"[4]. The treated group is that of workers in Quebec having children of an eligible age for childcare (that is, children aged 0-4) during the policy period while the control group would be all other workers in Quebec and workers in the rest of Canada.

I am interested in seeing whether the childcare policy influenced the concentration of workers into certain types of occupations. To achieve this, I assign to each worker the employment share of their occupation and estimate the impact of the policy on the average share of employment of a given group of occupation. The generic equation is:

[3] In 2004 there was an increase from $5.00 to $7.00 a day Baker et al. (2008). For our estimations this change should not affect the results, as I will use data from 1994 to 2003.

[4] This is to match the same period used by Baker et al. (2008)

$$y_{ipt} = \alpha + \gamma_1 Policy + \gamma_2 Quebec + \gamma_3 Kids + \gamma_4 Policy * Quebec + \gamma_5 Policy * Kids + \gamma_6 Quebec * Kids + \gamma_7 * Policy * Quebec * Kids + \mathbf{X}_{it}\beta + \varepsilon_{ipt} \quad (2.1)$$

I have included three levels in equation 2.1. The first level is the indicator variable *Policy*, which captures the aggregate factors that would cause changes in the outcome variable in the absence of the policy change. The indicator *Quebec*, the second level, captures the possible differences between the geographical groups prior the policy change, and the third level, *Kids*, is an indicator having children aged 0-4, and captures the possible differences between individuals with childcare aged kids and those who do not. The interaction $Policy * Quebec$ controls for other Quebec workers after the implementation of the child care policy, while $Policy * Kids$ for those workers in the rest of Canada affect by the policy with children aged 0-4. $Quebec * Kids$ controls for the workers in Quebec with children aged 0-4. $\mathbf{X}_{it}$ is a vector of individual characteristics that includes 7 age indicators, 9 education level indicators and year indicators[5][6], and y_{ipt} is the log of the share of the occupation where the individual i works in province p at time t. The parameter of interest here is γ_7, which is the Difference-In-Difference-In-Difference (DDD) estimator. The OLS estimate of $\hat{\gamma}_7$ can be expressed as follows

$$\hat{\gamma}_7 = (\bar{y}_{Q,K,2,\mathbf{x}} - \bar{y}_{Q,K,1,\mathbf{x}}) - (\bar{y}_{RC,K,2,\mathbf{x}} - \bar{y}_{RC,K,1,\mathbf{x}}) - (\bar{y}_{Q,NK,2,\mathbf{x}} - \bar{y}_{Q,NK,1,\mathbf{x}}) \quad (2.2)$$

where Q means Quebec, K kids, RC rest of Canada and 2 is the period after the policy. The DDD reflects the average change for people with childcare aged children in Quebec relative to the period before the policy, and net of the time effects for those not affected by the policy in Quebec and outside Quebec. I exclude the years 1998-1999 from the estimation in order to account for the lag in the implementation of the policy as well as the need for a control period free of any policy intervention.

[5] In some specifications I also include month and province indicators. The results are robust to these specifications.

[6] I included 7 age indicators grouped into 19-24, 25-29, 30-34, 35-39, 40-44, 45-49 and 50-54 years old, and 9 education level indicators going from some schooling to advance degree

The parameter γ_7 reflects the effect of the policy on the concentration of employment in a given set of occupations. A positive sign indicates that workers affected by the policy are now more concentrated in certain occupations, whereas a negative sign indicates less concentration.

To see how this would work an example would be useful. Suppose that there are only 4 sectors and 20 people in an economy, distributed as in table 2.1. Sectors are labelled by S_i for each $i = 1, ...4$. Sectors S_1 and S_2 are male dominated and each has a share of total employment of 0.3 while sectors S_3 and S_4 each represents a share of 0.2 of total employment and are gender balanced.

Table 2.1: Changes in Shares

Sector	*N*	*Men*	*Women*	*Share*
S_1	6	4	2	0.3
S_2	6	4	2	0.3
S_3	4	2	2	0.2
S_4	4	2	2	0.2

In a cross section data set, each individual that belongs to sector S_1 will have a value of the share in his sector of 0.3, therefore, in a regression setting as in 2.1 the estimated mean share of sectors in the economy would be a weighted sum of the shares using as weights the number of individuals in each sector as follows:

$$\overline{share} = \frac{6 * 0.3 + 6 * 0.3 + 4 * 0.2 + 4 * 0.2}{20} = 0.26$$

Note that this weighted average is minimized when the number of people is the same across sectors. In this example, if each sector has $N = 5$ the mean share will be 0.25. Note as well that this mean value would increase if the number of individuals in one sector increases. To illustrate the latter suppose I have a distribution of workers as in table 2.2. The mean share is therefore $\overline{share} = 0.265$ and so, as long as one sector is becoming more concentrated in terms of the people it employs, the weighted average will increase.

Now consider what would happen to the mean share if one wanted to evaluate specific subgroups, for instance in only the male dominated industries. Let these be sectors S_1 and

Table 2.2: Changes in Shares

Sector	*N*	*Men*	*Women*	*Share*
S_1	7	5	2	0.35
S_2	5	3	2	0.25
S_3	4	2	2	0.2
S_4	4	2	2	0.2

S_2 in our example. The mean share of employment is 0.3 and this mean can increase by two ways:

Movement of people within the male dominated sectors: suppose that 3 individuals move from sector S_1 to S_2 as in table 2.3. The mean share of employment would be 0.375 for this subgroup.

Table 2.3: Movement Within Sectors

Sector	*N*	*Men*	*Women*	*Share*
S_1	3	2	1	0.15
S_2	9	6	3	0.45

Movement of people between the male dominated and other sectors: Suppose that 2 individuals move from sectors S_3 and S_4 as in table 2.4. The average mean in this case would increase to 0.35

Table 2.4: Movement Between Sectors

Sector	*N*	*Men*	*Women*	*Share*
S_1	7	5	2	0.35
S_2	7	5	2	0.35

Therefore, in the regression framework used in this paper, an increase in the share of the male dominated occupations after the implementation of the affordable childcare policy in Quebec could be driven by two options: people moving within industries (*Intra Composition Effect*) or by people moving in from outside industries (*Inter Composition Effect*)[7]

[7] In a different work I study the effect of this policy in the entire distribution of our the skill indexes using Quantile Treatment Effects

During the late 1990s there were other policies affecting family/child benefits. In early 1998 the federal government of Canada created the National Child Benefit Supplement administered by the Canada Revenue Agency. Moreover, by the end of 1990s almost all the provinces created their own child support programs. However, Baker and Gruber (2005) found no evidence that there were strong variations in policies across Canada other than the new $5 per day policy in two parent families in Quebec[8].

In the same period of time, the Canada/Quebec Pension Plan Disability (C/QPPD) suffered modifications. I cannot see in the data who collects this benefit. However, these are unlikely to affect all the workers in our sample given the small amount of people that use this benefit[9].

In addition, the provinces of British Columbia and New Brunswick implemented a pilot program called the Self Sufficient Project, designed to provide evidence on the effects of a financial incentive on long-term welfare recipients aim to single parents with children (see for example Riddell and Riddell (2014)). In this paper we focus our attention on the sample of women coming from two-parents families, which makes unlikely that our results are affected by this program when comparing Quebec with the rest of Canada.

2.3 Results

To set this analysis in the context of previous literature, I show in table 2.5 the impact of the policy on different labour market outcomes. Each coefficient represents the estimation of DDD estimator γ_7 explained in section 2.2. Each column represents a sample restriction and each row a different outcome variable. The first column, *All*, uses the whole sample including single individuals. The second one, *All Women*, restricts the sample to all women both in two parent families and single mothers. The third column, restricts the sample to *Two Parent* families (married and in common law). Finally, the last column, *Women in Two Parent*, restricts the attention to women in this group; that is, excluding single mothers.

For *Two Parent* there are positive and significant effects on Full and Part time employ-

[8]See Appendix B.2 for a summary of changes in childcare policies in Canada

[9]Campolieti and Riddell (2012) show that around 2% of the individuals in their sample use a C/QPPD benefit, roughly 80,000 individuals.

ment as well as in Labour Force participation after the policy. The estimated change in these variables are 0.7%, 1.9% and 1.7% respectively. For *Women in Two Parent* families the only significant effect is in labour force participation, a similar qualitative result found in Baker et al. (2008) and Lefebvre and Merrigan (2008). There is a statistical significant negative effect in the Usual Hours Worked for all the samples except for two parent families. However, this effect is rather small compared to the average of this variable in the sample (around 35 hours).

Table 2.5: Impact of the Policy in Employment

	All (I)	All Women (II)	Two Parents (III)	Women in two parent (IV)
Full Time	0.001	0.005	0.007***	-0.0002
	(0.005)	(0.008)	(0.003)	(0.007)
Part Time	0.0002	-0.009***	0.019***	0.006
	(0.002)	(0.005)	(0.002	(0.005)
Labor Force Participation	0.001	0.001	0.017***	0.010***
	(0.002)	(0.003)	(0.002)	(0.003)
Usual Hours Worked	-0.962***	-0.083***	-0.343***	-0.274***
	(0.083)	(0.160)	(0.049)	(0.135)

Note: *, **, *** rejects the Null at 10, 5 and 1 percent level. Cluster-Robust standard errors by Province are in parenthesis. Sample is constructed from the LFS between 1994-2003 excluding 1998 and 1999. All the estimations control for Province dummies, Age dummies, Yearly time trends and Education dummies.

2.3.1 Short Run Effects

Similar to other papers in the literature table 2.5 shows that the Quebec Policy had an effect on the participation of women in the labour force. If households can afford better childcare, they could spend more time searching for better jobs, committing more time to employment, or investing in human capital. Consequently it might change the choice of occupations of workers affected by the policy and I should be able to see this in the concentration of occupations.

In order to assess the differential impact on other kinds of occupations, I classify occupations according to the 3 digits SOC classification and I group them in female and male dominated, and gender balance occupations. I define an occupation as gender balanced if the share of male (female) is between 40%-60%, and as male (female) dominated occupation if the share of male (female) is bigger than 60%. Table 2.6 shows the DDD parameter (γ) reflecting the effect of the policy on the average share of employment. Each cell represents the effect of the policy for the group of workers (column) and type of occupation (row). A positive sign in the estimator implies a higher concentration of individuals in the occupation group for a given sample.[10]

The estimates in table 2.6 show that concentration increased for gender balanced occupations after the policy; however, it seems that this result is not led by women because when restricting the sample to women, the result is not significant (columns II and IV). For female dominated occupations, is clear that the policy generated a concentration in these types of occupations as the estimates are positive for all the sample restrictions, ranging from 0.055 for all the workers, to 0.034 when I restrict the sample to women in *Two Parent* families. Moreover, it seems that the policy decreased the concentration in male dominated occupations for all the samples considered. The estimates go from -0.047 for all the sample to -0.112 when restricting only to women in families. Finally, the effect of the policy for all the occupations was positive, implying a higher concentration; note that these estimates are small in magnitude as they go from 0.015 to 0.008 when restricting the sample to only women in two parent families.

In order to incorporate information from the skill index, I use a finer set of occupations, the 4-digit SOC classification. This allows me to capture moves within occupations that initially were grouped into the 3-digits classification and naturally were not counted as changes in the estimations in table 2.6. In other words, it allows me to capture a larger number of intramovement within the occupation group.

In addition to the gender segregation classification, I classify the occupations in terms of their skill requirements. For this, I construct 3 skill indexes from information in the O*Net data set, using Confirmatory Factor Analysis (CFA). The indexes represent cognitive, social and physical abilities required by each occupation, and are weighted using the LFS individual weight so changes in the index can be interpreted as standard deviation changes from the

[10] For the 3-Digits SOC it was not possible to construct skill indexes as the information of the skills required for each occupation in the O*Net sample is only available for a very limited categories and there is not a clear map between the skills required for the occupations in 4-Digits codes and 3-Digits ones.

Table 2.6: Effect on Share of Employment 3-Digits SOC

	All (I)	All women (II)	Two Parents (III)	Women in two parent (IV)
Gender Balanced	0.034***	0.014	0.027***	0.010
	(0.005)	(0.010)	(0.007)	(0.017)
Female Dom	0.055***	0.048***	0.035***	0.034***
	(0.007)	(0.011)	(0.008)	(0.015)
Male Dom	-0.047***	-0.075***	-0.050***	-0.112***
	(0.008)	(0.023)	(0.010)	(0.026)
All Occ	0.015***	0.023***	0.009***	0.008**
	(0.005)	(0.006)	(0.004)	(0.005)

Note: *, **, *** rejects the Null at 10, 5 and 1 percent level. Cluster standard errors by province are in parenthesis. The samples are constructed from the LFS between 1994-2003 excluding 1998 and 1999. All the estimations control for Province dummies, Age dummies, Yearly time trends and Education dummies.

distributions of skills in the Labour Force in Canada[11] I then choose the occupations that are intensive in cognitive, social and physical abilities measured as those that fall in the top 25% levels of the distribution of skills. I also classify individuals in high paid occupations using the Canadian census from 1996 to check which occupations are in the top 25% in terms of earnings. Appendix B.1 explains the construction of these indexes and Appendix ?? list the occupations in each group.

Table 2.7 presents the core results of this study. The dependent variable is, again, the logarithm of the share of employment for each occupation of the detailed SOC classification at a 4-digit level. In gender balanced occupations, the effect is positive and significant, which suggests a concentration in these type of occupations. Note, that the estimates are now statistically significant for the sample of women and generally larger in magnitude compared to table 2.6. This is to be expected as using a finer set of occupations allows me to capture intramovement that were not considered while using the 3-digit classification. This remains true for all the other estimations, particularly for male dominated occupations. The results are negative for this group, suggesting again a lesser concentration in these occupations, with estimations ranging from -0.093 to -0.315. The effect for female dominated occupations, however, is generally not significant and even negative (column II). Since I observe higher

[11]Increasingly, labour economic studies use the information contained in O*Net to better characterize the implicit heterogeneity in occupational choice (see for example Adserà and Ferrer (2014), ? and Arcila et al. (2016)

concentration at the aggregate level, this is consistent with less concentration in female dominated occupations driven by intraoccupational mobility.

The effects for cognitive occupations are among the highest in magnitude in this table. It goes from -0.187 to -0.209 and it suggests that the occupations in these categories are less concentrated after the policy. This could be individuals working in a more diverse range of cognitive intensive occupations, or to workers leaving cognitive intensive occupations. The estimates for social occupations suggest a decrease in concentration; however, this is not led by women as the estimates are not statistically significant in columns II and IV. For physical occupations, the effects are high in magnitude (they range from -0.162 to -0.239) and also suggest less concentrated occupations. The change in the highest paid occupations follow the same line as before, though the magnitude of the estimates is smaller. They suggests a decrease in concentration in these type of occupations. Finally, the effect in all the occupations is negative (it was positive in table 2.6). This is again probably capturing lower intramobility effects that were not captured at the aggregate aggregate.

Table 2.6 and 2.7 show two different effects. Taken together, results suggest that within female and male dominated occupations there was a dispersion, whereas in gender balanced occupation there was a concentration. Using the 3-digit classification makes relatively more likely to capture mobility between group of occupations (people moving, for example, from male dominated to female dominated) than using 4-digit classification. The 4-digit classification is more likely to capture intramobility (people moving within a group of occupation).

2.3.2 Long Run Effects

Since enough time has passed, I am also able to establish the long term impact that this policy might have as well. For this reason I estimate a similar equation as 2.1 adding the following:

Table 2.7: Effect On The Share Of Employment. 4-Digits SOC

	All (I)	All Women (II)	Two Parents (III)	Women in two parent (IV)
Gender Balanced	0.019***	0.133***	0.056***	0.180***
	(0.010)	(0.025)	(0.009)	(0.020)
Female Dom	0.024***	-0.017**	0.001	-0.019
	(0.010)	(0.009)	(0.013)	(0.013)
Male Dom	-0.093***	-0.215***	-0.145****	-0.315***
	(0.008)	(0.028)	(0.008)	(0.024)
Cognitive Occ	-0.187***	-0.209***	-0.176***	-0.173***
	(0.021)	(0.037)	(0.018)	(0.038)
Social Occ	-0.092***	-0.003	-0.093***	-0.020
	(0.028)	(0.044)	(0.026)	(0.047)
Physical Occ	-0.162***	-0.239***	-0.151***	-0.225***
	(0.017)	(0.023)	(0.014)	(0.025)
Highest Pay	-0.095***	-0.103***	-0.080***	-0.146***
	(0.028)	(0.032)	(0.033)	(0.037)
All Occ	-0.007	-0.025***	-0.040***	-0.045***
	(0.010)	(0.013)	(0.006)	(0.013)

Note: *, **, *** rejects the Null at 10, 5 and 1 percent level. Cluster-Robust standard errors by province are in parenthesis. Sample is constructed from the LFS between 1994-2003 excluding 1998 and 1999. All the estimations control for Province dummies, Age dummies, Yearly time trends and Education dummies.

$$
\begin{aligned}
y_{ipt} = \alpha + \gamma_1 Policy + \gamma_2 Quebec + \gamma_3 Kids + \gamma_4 Policy * Quebec + \gamma_5 Policy * Kids + \\
\gamma_6 Quebec * Kids + \gamma_7 * Policy * Quebec * Kids + \mathbf{X}_{it}\beta + \\
\gamma_8 Policy_L + \gamma_9 Policy_L * Kids + \\
\gamma_{10} Policy_L * Quebec + \gamma_{11} Policy_L * Kids * Quebec + \varepsilon_{ipt}
\end{aligned} \tag{2.3}
$$

where y_{ipt} is the log of the share of employment for each occupation in province group p in time t for the individual i. $Policy_L$ is a dummy variable that takes the value of 1 after 2004 and the other variables are as explained before. *Policy* remains as a dummy variable that takes the value of 1 between 2000 and 2003. Therefore in this estimation I separate the effect of the policy in two parts: a short run and long run effect. The estimated coefficient, γ_7, in specification 2.3 is numerically equal to the one estimated in 2.1. In this specification I expand my sample to 2015, which allows us to capture the long run trends in the effect of the policy. Tables 2.8 and 2.9 report estimation for the coefficient γ_{11} that captures the DDD of the long run effects.

Similar effects are found in the long run when I use the SOC 3-digits classification (table 2.8). The estimations for gender balanced occupations show a positive effect, which suggests a concentration in these occupations. This is driven by the sample of women which is a different effect when compared to table 2.6. There are positive estimates in female dominated occupations, suggesting a concentration in the long run but not significant effects for *Two Parent* families. When compared to the estimations in table 2.6, the coefficients are similar in magnitude for the sample of *All Women*. The effects for male dominated occupations is negative, which suggest a lesser concentration in these type of occupations; the magnitudes are also similar to the short run estimations, going from -0.067 to -0.157. Finally, the effect on *All* the occupations is positive but only significant for the sample of *All Women*.

Table 2.9 shows the estimates for the finer 4-digits classification. The effect for gender balanced occupations is only significant for *Women in Two Parents* families and positive as in table 2.8. The estimations for female dominated occupations are positive for all the samples, suggesting a concentration of these occupations when using the 1994-2015 sample. These

Table 2.8: Effect On The Share Of Employment. 3-Digits SOC Long Run

	All (I)	All women (II)	Two Parents (III)	Women in two parent (IV)
Gender Balanced LR	0.001	0.018**	0.018	0.033***
	(0.012)	(0.011)	(0.014)	(0.014)
Female Dom LR	0.037***	0.045***	0.021	0.023
	(0.017)	(0.018)	(0.021)	(0.023)
Male Dom LR	-0.067***	-0.151***	-0.062***	-0.157***
	(0.007)	(0.011)	(0.008)	(0.008)
All Occ LR	0.003	0.023***	0.006	0.011
	(0.009)	(0.008)	(0.012)	(0.013)

Note: *, **, *** rejects the Null at 10, 5 and 1 percent level. Cluster standard errors by province are in parenthesis. Sample is constructed from the LFS between 1994-2015 excluding 1998 and 1999. All the estimations control for Province dummies, Age dummies, Yearly time trends and Education dummies.

estimates are only significant for *Two Parent* families. For male dominated occupations the estimates remain negative, suggesting a less concentration with significant values and high coefficients in magnitude.

As in the estimations for the short run, the effects in cognitive occupations are negatives, suggesting a concentration in these occupations. The estimated values go from -0.059 in the *All Women* sample to -0.105 in the sample when I use all the information. Note that, however, the estimates for *Women in Two Parent* families is not significant. Same effect is found for social occupations which seem to have a less concentration after the policy. Physical intensive occupations show a negative estimate for all the sample, but this seems not to be driven by the sample of women. The estimates for the highest paid occupations are negative, same sign as in table 2.7 though in the long run they have a higher magnitude.

2.4 Concluding Remarks

In this paper I provide, to the best of my knowledge, the first analysis of the impact of the Universal Childcare program in Quebec on the concentration of occupations. I estimate a Difference-in-Difference-in-Difference model to assess how the affordable Child Care Policy changed the share of employment in Quebec for female dominated, male dominated, and gender balanced occupations as well as the impact in the share of employment in occupations

Table 2.9: Effect On The Share Of Employment. 4-Digits SOC Long Run

	All (I)	All Women (II)	Two Parents (III)	Women in two parent (IV)
Gender Balanced LR	-0.010	0.040	-0.021	0.070***
	(0.031)	(0.038)	(0.029)	(0.032)
Female Dom LR	0.008	0.013	0.055***	0.059***
	(0.010)	(0.009)	(0.009)	(0.009)
Male Dom LR	-0.084***	-0.212***	-0.111***	-0.226***
	(0.011)	(0.019)	(0.007)	(0.027)
Cognitive Occ LR	-0.105***	-0.059***	-0.082***	-0.011
	(0.016)	(0.034)	(0.014)	(0.031)
Social Occ LR	-0.137***	-0.084***	-0.111***	-0.057
	(0.029)	(0.049)	(0.024)	(0.041)
Physical Occ LR	-0.089***	-0.072	-0.063***	-0.015
	(0.017)	(0.046)	(0.019)	(0.048)
Highest Pay LR	-0.106***	-0.187***	-0.097***	-0.206***
	(0.013)	(0.036)	(0.021)	(0.039)
All Occ LR	-0.003	0.014	-0.011	0.020***
	(0.010)	(0.010)	(0.013)	(0.010)

Note: *, **, *** rejects the Null at 10, 5 and 1 percent level. Cluster standard errors by province are in parenthesis. Sample is constructed from the LFS between 1994-2015 excluding 1998 and 1999. All the estimations control for Province dummies, Age dummies, Yearly time trends and Education dummies.

that are intensive in cognitive, social and physical abilities. I also explore the impact on high paid occupations for a different set of sample restrictions.

In general, the results suggest that the average share of employment in female dominated and gender balanced occupations increased in Quebec after the policy compared to the rest of Canada, suggesting a concentration of workers in these occupations. However, the estimates suggest a lower concentration of occupations in cognitive, social, and physical occupations. The results hold for the long run specification as I found consistent changes in the average share of employment for the same groups of occupations.

These findings suggest that it is plausible that after the policy, occupations that are traditionally female dominated or gender balance occupations became more concentrated. It seems that even though the policy increased the labour force participation of women, these could be intramovement within occupations that are gender balanced and female dominated. I also found a reduction in the average share of employment in high paid and cognitive intensive occupations for women in two parent families, which suggests a lesser concentration in these group of occupations. This holds true in the long run as well.

For women in *Two Parent* families, the policy decreased the average share of employment in physical intensive occupations, which are, on average, lower paid than cognitive intensive occupations. However, this women seem to concentrate in gender balanced occupation after the policy.

One caveat of this study is the fact that prior to 1997 there were some childcare benefits targeted towards low-income individuals. Before this year (and continuing after 1997) there were also refundable tax credits at a rate that depended on family income: from 75 percent for those with the lowest incomes down to 26 percent for those with family incomes greater than $48,000 Baker et al. (2008). Under the new policy, children receiving the $5.00 childcare benefit were not allowed to apply for any other subsidy. Thus, the pre-1997 child care policies targeted low-income families implying that the effect of the Family Policy on the effective price of child care varies with family income Baker et al. (2008). This is problematic as I will likely only be capturing the effect of the new childcare policy on individuals that were not eligible for the previous subsidy or those who changed subsidies. For those who did not change subsidies, I will not be able to identify the effect of the new policy since I cannot observe the wage before 1997 using the LFS.

There is extensive literature on the effects of childcare policies, most of them focused in the effect on the behavioural outcomes of the children and the quality of child care supply. In this paper, I find that the policy had some effect in the occupational choices of parents in Quebec. I uncover new results on the labour force outcomes for the parent of these children and its effects on the average share of employment and the concentration in groups of occupations.

This is an initial exploratory exercise on whether the Affordable Childcare Policy in Quebec changed the occupational choices and the distributions of workers across occupations. However, I cannot pin-down the size of intramobility and intermobility between and across group of occupations, which would be interesting. In the next chapter, I use newly developed methods to estimate Lorenz Dominance and Quantile Treatment Effects, that would allow me to estimate the change in the entire distribution of skill in occupations.

Chapter 3

Distributional Effects of the Affordable Child Care Policy on the Skills

Andres Arcila & Thomas Parker

3.1 Introduction

Understanding changes in the skill distribution has been an exciting and extensive area of research in the labor economics literature. Since the very influential papers by Autor et al. (2003), Autor et al. (2006) and others, on computerization and the polarization of the US labor market, many have tried to understand the changes in the skill requirement of occupations and its effects in the wage inequality. In this paper, we are interested in understanding the effect that childcare policies may have on the type of jobs that people take. Specifically, we use exogenous variation given by a policy change in the province of Quebec in Canada to analyze the changes in the distribution of skills contained in the jobs people work.

Substantial evidence has been gathered to show that childcare policies affect the labor force participation of women. We believe that this can also affect the type of jobs that people do. In previous research we showed evidence that the policy had an impact in the concentration in different types of occupations. We argued that the movement of individuals across occupations can be reflected in the type of occupations people take after the policy. Here we investigate how these movements affect the conditional and unconditional distribution of a skill index. The skill indexes are constructed similarly to others in the literature. We use principal component analysis to reduce the many attributes of jobs included in the O*Net database to a single index, measuring the amount of a given skill required for a particular job. We construct five skill measurements that account for analytical, physical, interpersonal, visual and fine motor skills. Our results are based on the assumption that the skill requirements for occupations in the O*Net data set, which is a US based sample, reflects the requirements in the same occupations in Canada.

In 1997, the province of Quebec introduced a subsidy to provide affordable childcare for children under 5. The core of the policy was to provide regulated childcare centers to kids aged 0-4 in Quebec at a cost of $5.00 per day to parents. There is substantial evidence that the policy increased the labor force participation of women, influenced the cognitive and behavioral outcomes of children and affected the gender gap in academic achievements (Baker et al., 2008; Kottelenberg and Lehrer, 2014; Lefebvre and Merrigan, 2008; Tougas, 2002)

We use newly developed methods to test for stochastic and Lorenz dominance (Barrett et al., 2014, 2016; Linton et al., 2010) to assess whether the distribution of skill requirements in occupations in Quebec is different before and after the policy relative to changes in the distribution of skills in the Rest of Canada. We complement this analysis by calculating Quantile Treatment Effects using a propensity score re-weighting technique developed by Firpo (2007) to measure these differences across the distributions. To the best of our knowledge, we are the first to offer evidence of the impact of the Quebec childcare policy on the distribution of job skill content. We also estimate the effect by gender in order to see how the distributions of the skills in the occupations that women take changed after the policy in Quebec and the rest of Canada.

Our results suggest that the distribution of the interpersonal, physical, visual, and fine motor skills index in Quebec, for individuals in two parent families with children aged 0-4, stochastically dominates the distribution of skills for the same group of parents in the rest of

Canada in 1994, whereas in 2004 the dominance is reversed. However, the distribution of the analytical skill index in Quebec dominates the one for the rest of Canada in both years for the same group of parents. The estimation of Quantile Treatment Effects strengthen these results by showing that the largest changes in the analytical skill index happened in occupations at the median ability level of the Canadian Labour force. This means that the studied group in Quebec were working on occupations that require more of these abilities in 1994, but these parents in Quebec were working in occupations with less analytical skill requirements in 2004 than parents in the rest of Canada. This is an interesting result as it could suggests that the affordable childcare policy potentially helped to move the distribution of workers across occupations. Moreover, these occupations are associated with less job quality and are less paid on average. Note, however, that these are not a causal effects, as we only compare two years for two different groups.

The rest of the paper is organized as follows. Section 3.2 explains the O*Net data set and describes in detail the skill index. Section 3.3 shows the procedure on how to test for stochastic and Lorenz dominance followed by section 3.4 that explains the procedure to estimate the conditional and unconditional Quantile Treatment effects. Section 3.5 shows the core of the results and section 3.6 concludes.

3.2 The O*Net Data and The Skill Index

The Occupational Information Network (O*Net) is a US-based database that contains detailed information on abilities needed to perform different tasks for more than 1000 occupations. Is being developed under the sponsorship of the US Department of Labor/Employment and Training Administration (USDOL/ETA) through a grant to the North Carolina Department of Commerce which operates the National Center for O*Net Development. The O*Net, which replaced the Dictionary of Occupational Titles, is a useful source of detailed and comprehensive information for these occupations. It contains information on formal education, job training, and other qualifications necessary to conduct tasks for each occupation, as well as different abilities and categories of knowledge required by its workers. Increasingly, labour economic studies use the information contained in O*Net to better characterize the implicit heterogeneity in occupational choice (see for example Adserà and Ferrer (2014); Arcila et al. (2016); Imai et al. (2018)).

The survey contains information that can be used to construct a portfolio of skills for each occupation. For instance, there are occupations that require knowledge of computer programming and statistics. One can assume that the skills needed to conduct this job are intensive in cognitive abilities. Other O*Net information includes aptitudes, temperaments, tasks, and environmental conditions, that can potentially reveal information about the skills needed for other occupations. For example, occupations that involve moving and handling heavy objects might suggest the need for physical skills.

Many of these characteristics are related to each other or could be summarized in a single value. We use Confirmatory Factor Analysis (CFA), an approach similar to Yamaguchi (2012), to reduce the dimensionality of the information in O*Net to construct a set of skill indexes that represent the underlying abilities needed to conduct different tasks in occupations. This is similar to Imai et al. (2018) where the underlying assumption is that the large set of O*Net job characteristics can be summarized by a small number of fundamental skill requirements.

We separate the O*Net variables a priori into groups of job characteristics such that all attributes in each group are associated with a common skill component, then we estimate principal components over the set of variables checking that which of the variables are contributing to the score. We construct five indexes covering both cognitive and non-cognitive job skills that line up with previous work in the area to facilitate comparison. Specifically, we use two cognitive indexes representing interpersonal (social) skills and analytical (quantitative) skills and three indexes for non-cognitive or manual skills, including fine motor skills, physical strength, and visual skills.

To connect the information regarding skills required of occupations found in O*Net to occupations in the Labor Force Survey of Canada (LFS), we rely primarily on a series of crosswalks designed to match occupation codes from O*Net to Standard Occupation Codes (SOC) used in the United States and then from SOC to the NOC codes now used in Canada. Using these crosswalks, we are able to match most occupations. We then manually reviewed unmatched LFS occupations to find appropriate matches in O*Net. Only a few occupations are left unmatched.

To facilitate interpretation of the skill variables the factor analysis uses as weights the distribution of the skills in the Canadian workforce. As such, a skill score of zero describes the level of skill used by the average worker in the Canadian workforce. Also, a unit of the skill score (with mean zero) can be interpreted as one standard deviation in the skill distribution of the Canadian working population. It is important to mention that the indexes measure the skill required to conduct an occupation rather than the actual skill of the individual

3.2.1 The Labor Force Survey

We use the confidential microfiles of the Labor Force Survey (LFS) in 1994 and 2004. The LFS is a rotating panel that is conducted monthly to produce unbiased estimates of various statistics including the unemployment rate. The data uses a stratified multistage probability sample design and interviews approximately 59,000 Canadian households each month and each individual is followed for six months.

The survey contains information about the characteristics of the job, like being covered by a union agreement, whether the job is a part time or full time job, the reasons why the individual chooses to be in a part time job, etc. We use the first time the individual appears in the survey and restrict the sample to workers aged 19 to 55 that are in the labor market, that is, that reported during the survey that they were employed or looking for a job and those who were not self-employed. From the survey, we are able to link individuals' characteristics with their jobs, including the 4-digit occupation code (NOC) to match the information from he O*Net.

We focus on these two periods because they give us 3 years before the beginning of the childcare policy and 3 years after the complete implementation of it. To correctly compare the population in the treated and control groups we find the people in 1994 that could potentially be eligible for the subsidy, i.e. those with kids younger than 4 years, and construct a matched sample outside of Quebec using a propensity scored-based matching. We conduct a similar approach for the 2004 sample. Doing this guarantees that we are comparing the correct individuals inside and outside Quebec[1].

[1]Selection is not a problem in this case. All individuals with kids between 0-4 years old were eligible

3.3 Stochastic Dominance

Stochastic Dominance is a useful concept to test whether the Cumulative Distribution Function of a variable is always below of another. In the context of this paper, if we observe that the CDF of a given skill index for a group stochastically dominates the corresponding CDF of the other groups, it indicates that individuals in the group that "dominates" work on occupations that require more of that particular skill than the occupations held by workers in the "dominated group. Since stochastic dominance is a global concept, this will be true for every different quantile of the distribution. Therefore, this technique would allow us to identify changes in the skill requirements in occupations in a potentially revealing way and correlate this changes with policy changes. In this section we explain in detail this definition and the statistical test that we use.

We follow closely the notation and definitions in Linton et al. (2010). Let $W = \{X_0, X_1\}$ be the realization of a pair of continuous outcome variables, in this case this would be the realization of any of the 5 indexes constructed in two different periods of time. Let $F_k(x)$ be the distribution function of the k-th random variable X_k, $k = 0, 1$. We define

$$D_k^{(s)}(x) \equiv \int_{-\infty}^{x} D_k^{(s-1)}(t)dt$$

with $D_k^{(1)}(x) \equiv F_k(x)$. We say that X_0 stochastically dominates X_1 at order s if $D_0^{(s)}(x) \leq D_1^{(s)}(x)$.

To test this statement let's define $h_{01}^{(s)}(x) \equiv D_0^{(s)}(x) - D_1^{(s)}(x)$. The null hypothesis of main interest takes the following form:

$$H_0 : h_{01}^{(s)}(x) \leq 0$$

for all $x \in X$

$$H_1 : h_{01}^{(s)}(x) > 0$$

for some $x \in X$

for the subsidy in the childcare centers and virtually all spots were taken. Quality of the childcare and availability of open positions should also not be a concern. See for example Baker et al. (2008); Kottelenberg and Lehrer (2014); Lefebvre and Merrigan (2008); Tougas (2002)

The null hypothesis represents the stochastic dominance of X_0 over X_1, whereas the alternative corresponds to no such incidence. We focus our attention on two types of test. The Cramer-von Mises (CV) defined as follows:

$$c_s = \left(\int_X \left(\max\left(0, h_{01}^{(s)}(x)\right) \right)^2 dx \right)^{1/2}$$

and the Kolmogorov-Smirnov (KS) type test:

$$k_s = \sup_X (\max(0, h_{01}^{(s)}(x)))$$

in both cases X represents the set contained in the union of the supports of X_1 and X_0. To get the asymptotic distribution of these two statistics, we propose a bootstrap procedure to get the asymptotically valid critical values based on Linton et al. (2005) and Linton et al. (2010) that we explain in subsection 3.3.2.

3.3.1 Second Order Dominance and Lorenz Dominance

Second Order Dominance (SOSD) is also of interest. Testing for this, we can assess the effect on inequality in the distributions of skills for two different groups. SOSD is a well-known method of quantifying the degree of inequality in the distribution of some measure of welfare applied to a population (often wealth and income distributions). In the context of this work, it will allow us to identify concentrations in the skill requirements of occupations for the two groups that we study. Understanding these changes in concentration allow us to estimate the possible effects in the type of occupation people hold. In other words, to the extent that this could be interpreted as a causal effect, testing for Lorenz Dominance could help us understand what are the possible effects of the affordable child care policy in the concentration of skill requirements for occupations.

Let τ index a quantile level in $\mathcal{T} = [\epsilon, 1-\epsilon]$ for $0 < \epsilon < 1/2$, and suppose that the quantile functions associated with the distributions of Y_1 and Y_2 are $Q_1(\tau)$ and $Q_2(\tau)$. The Lorenz curve for distribution k is defined as

$$L_k(\tau) := \frac{\int_{-\infty}^{Q_k(\tau)} yF_k(y)dy}{\int_y yF_k(y)dy} = \frac{\int_0^\tau Q_k(s)ds}{\int_0^1 Q_k(s)ds}, \tag{3.1}$$

where the second equality uses the transformation $s = F_k(y)$ and it is assumed that $Q_k(s) = F_k^{-1}(s)$ and the distribution is continuous. One can also construct a conditional Lorenz curve

$$L_k(\tau|x) = \frac{\int_0^\tau Q_{Y_k|X_k}(s|x)ds}{\int_0^1 Q_{Y_k|X_k}(s|x)ds}. \tag{3.2}$$

A Lorenz curve can be thought of as similar to the Gini index, except that the Gini index condenses all the information that the Lorenz curve offers into a single (index) number. Lorenz curves offer more information and can be instructive to make a visual check of a distribution.

Quantile regression is a natural tool to estimate the above conditional Lorenz curves in a semiparametric way. A quantile regression model generally has the form $Q_{Y|X}(\tau|x) = g(\tau, x)$. The most basic quantile regression takes g to be a linear function of x, but curves that relax this restrictive functional form can also be considered. A linear quantile regression model links response $Y \in \mathbb{R}$ and explanatory variables $X \in \mathbb{R}^p$ together through the model

$$Q_{Y|X}(\tau|x) = x^{'}\beta(\tau). \tag{3.3}$$

This model allows covariates to have a different effect on the response at different points in the distribution, indexed by quantile levels τ. Combining the linearity of the model while allowing changing effects over different quantiles results in a convenient semiparametric model of the effect of covariates on the entire conditional distribution of the response. Conditional on X, this model can be viewed as a stochastic process $\hat{\beta}(\tau)$, $\tau \in \mathcal{T}$.

Now define a quantile regression Lorenz curve as the integral of a quantile regression process. Using the model (3.3) and the definition of the conditional Lorenz curve (3.2) this process is parameterized like:

$$QL_k(\tau|x) = \frac{x\int_0^\tau \beta(s)s}{x\int_0^1 \beta(s)s}. \tag{3.4}$$

Similar to Barrett et al. (2014), consider the uniform (over some interval $\mathcal{T}$) hypotheses

$$H_0 : QL_1(\tau|x) \leq QL_2(\tau|x) \quad \text{for all } \tau \in \mathcal{T} \qquad \text{(dominance)}$$

$$H_1 : QL_1(\tau|x) > QL_2(\tau|x) \quad \text{for some } \tau \in \mathcal{T}. \qquad \text{(non-dominance)}$$

This null hypothesis is that distribution 2 dominates distribution 1 in the sense that its Lorenz curve is everywhere closer to the 45-degree line, which implies distribution 2 is uniformly "more equal" than distribution 1. This form of the hypothesis checks whether the null appears to be true for all possible quantile levels, and not just a few selected levels. It is similar to recent investigations of stochastic dominance and other similar criteria (Barrett and Donald, 2003; Barrett et al., 2014, 2016; Linton et al., 2005, 2010). However, the conditional nature of the test here has been considered less often, with the notable exception of the survey in Donald et al. (2012). We consider a fixed value $X = x$.

We design a statistic that look for deviations from the null in order to test the uniform Lorenz dominance hypothesis. We use both statistics explained before: the one-sided Kolmogorov-Smirnov statistic and the one-sided Cramér-von Mises statistic. Let

$$\Lambda_n(\tau|x) := \sqrt{\frac{n_1 n_2}{n_1 + n_2}} \left(\widehat{QL}_1(\tau|x) - \widehat{QL}_2(\tau|x) \right). \tag{3.5}$$

Then these statistics can be written

$$k_s := \sup_{\tau \in \hat{\mathcal{T}}} (\max(0 \vee \Lambda_n(\tau|x))) \tag{3.6}$$

$$c_s := \int_{\hat{\mathcal{T}}} (\max(0 \vee \Lambda_n(\tau|x)))^2 \, \tau. \tag{3.7}$$

These statistics are defined on an estimate of the contact set $\hat{\mathcal{T}} = \left\{ \tau : \left| \hat{F}_1 - \hat{F}_0 \right| \leq \frac{c}{\log(N)} \right\}$. Linton et al. (2010) provide regularity conditions sufficient to ensure that the contact set can be consistently estimated.

3.3.2 Bootstrap Procedure

We propose a bootstrap procedures for First and Second Order Stochastic Dominance as follows. We draw $\left\{W_{i,b}^{*}\right\}_{i=1}^{N}$, $b = 1, \ldots, B$, with replacement from the empirical distribution of $\{W_i\}_{i=1}^{N}$. Then we construct estimators of the CDF, $F_{0,b}^{*}(x)$ and $F_{1,b}^{*}(x)$ for each $b = 1, \ldots, B$ given the bootstrap sample $\left\{W_{i,b}^{*}\right\}_{i=1}^{N}$. Given the bootstrap estimator $F_{0,b}^{*}(x)$ and $F_{1,b}^{*}(x)$ we construct the bootstrap empirical process $h_{10}^{*}(x) \equiv D_{1}^{*(s)}(x) - D_{0}^{*(s)}(x) - D_{1}^{(s)}(x) + D_{0}^{(s)}(x)$ for $b = 1, \ldots, B$ where for $k = 0, 1$

$$D_{k,b}^{*(s)}(x) \equiv \int_{-\infty}^{x} D_{k,b}^{*(s-1)}(t)dt$$

with $D_{k,b}^{*(1)}(x) \equiv F_{k,b}^{*}(x)$. Then we define

$$\mathcal{T} = \left\{W_{i,b}^{*} : \left|F_{1,b}^{*} - F_{0,b}^{*} - (F_{1,b} - F_{0,b})\right| \leq \frac{c}{\log{(N)}}\right\}$$

Finally we propose the following bootstrap test statistic for Cramer-von Mises :

$$c_{s,b}^{*} = \left(\int\limits_{\hat{X}} \left(\max(0, h_{10}^{*(s)}(x))\right)^2 dx\right)^{1/2}$$

and the Kolmogorov-Smirnov

$$k_s^{*} = \sup_{\hat{X}} \left|\max(0, h_{10}^{*(s)}(x))\right|$$

.

To test Lorenz Dominance, we should change the KS and CV statistics for the formulas given in 3.6 considering that $h_{01}^{*(s)} = \Lambda_n(\tau|x)$ and apply the same bootstrap procedure. The bootstrap critical values for both statistic are obtained by

$$t_{\alpha,N,B}^{*} \equiv \inf\left\{a : B^{-1} \sum_{b=1}^{B} 1\left\{c_{s,b}^{*} \leq a\right\} \geq 1 - \alpha\right\}$$

yielding an α-level bootstrap test: $1\left\{c_s > t_{\alpha,N,B}^{*}\right\}$. Thus, we reject the null of dominance if the calculated k_s^{*} or c_s^{*} are bigger than $t_{\alpha,N,B}^{*}$.

Clearly, the last procedure works for a one sided dominance hypothesis. We are also interested in testing whether the distribution of the skill index is the same in the two periods. This implies a two sided hypothesis and the procedure is straightforward as the integration support and the domain of the supremum would be given by X instead of $\mathcal{T}$ in the CV and KS statistics respectively.

3.4 Quantile Treatment Effect (QTEs)

This section presents the main estimation equation for both the conditional and unconditional QTEs. We first present the estimation procedure for the QTE and its properties.

3.4.1 Conditional and Unconditional Quantile Treatment Effects

Our goal is to estimate the distributional effect of the affordable child care policy via treatments effects through conditional distributions of the skill index given a set covariates and a treatment status indicator. We consider the estimation of the Conditional Quantile Treatment on the Treated Effect (CQTT) given $X_i = x$ which measures the Conditional Quantile Treatment on the Treated Effect within a subpopulation of individuals with treatment status $D_{it} = 1$. The CQTT given $x \in X$ at $\tau \in \mathcal{T}$

$$\Delta_x^{QTT}(\tau) = F^{-1}_{Y_t(1)|X=x,D_t=1}(\tau) - F^{-1}_{Y_t(0)|X=x,D_t=1}(\tau)$$

where $F^{-1}_{Y_t(j)|X,D_t}$ is the quantile function of $Y_{it}(j)$ conditional on X_i and D_{it}, given by

$$F^{-1}_{Y_t(j)|X,D_t}(\tau) := \inf\left\{y \in : F_{Y_t(j)|X,D_t}(y) \geq \tau\right\}$$

This estimation is based on two key assumptions. The first one is the linear model for potential outcomes and the second one is the selection on observables. These two assumptions imply that we can recover the unknown parameters of the potential outcomes from the joint distribution of the observed variables Y, X and D. Then the coefficient can be recover using the classical quantile regression estimator of Koenker and Bassett Jr (1978) defined by:

$$(\beta(\tau), \delta(\tau)) = \arg\min_{\beta,\delta} \sum \rho_\tau(Y_i - X_i\beta - D_i\delta)$$

where $\rho_\tau(u) = u \times \{\tau - 1\,(u < 0)\}$ is the common quantile regression check function. In this case, we implement the propensity score re-weighting approach developed in Firpo (2007). This methodology calculates the propensity score as $p(x) = P(D = 1|X = x)$, and the propensity score re-weighting approach rewrites the conditional CDF as a single unconditional moment that depends on the propensity score and the realization of Y. The propensity score is estimated in a first step and then a sum of weighted check functions is minimized in a second step to obtain an estimate of the QTEs. This technique allows some flexibility in trading off stronger assumptions with computational complexity.

We will also consider unconditional QTEs which has some advantages over the conditional effects and is given by:

$$\Delta^{QTT}(\tau) = F^{-1}_{Y_t(1)}(\tau) - F^{-1}_{Y_t(0)}(\tau)$$

The advantages of estimating the unconditional QTEs arise in the asymptotic properties. Suppose that we were interested in the average effect, including covariates might increase the efficiency in the estimation with a particular property that the estimate remain unchanged asymptotically. However, this property is not true for QTEs. Including covariates that are independent from the treatment can change the limit of the estimated conditional QTEs. However, it does not change the unconditional treatment effects if the assumption of the model are satisfied. Moreover, the unconditional effect can be estimated consistently at the $\sqrt{n}$ rate without any parametric restriction, something not possible with the conditional effect (Frolich and Melly, 2010). Therefore, we integrate the QTEs over the distribution of the covariates to get an estimate of the unconditional QTEs by using these set of covariates that leads to an increase in the efficiency (Firpo, 2007).

3.5 Results

This section contains the test for First and Second Order Stochastic Dominance using both, CV and KS statistics and the estimations of the Quantile Treatment Effects (QTE) with and without covariates. We first present Stochastic Dominance followed by the estimates of the QTEs.

3.5.1 Stochastic Dominance

Our purpose here is to check whether the distribution of the skill index for the individuals eligible for the subsidy in Quebec stochastically dominates the distribution of the index for the comparable group outside this province; thus, our treatment group will be the individuals with kids aged 0-4 in Quebec and the control group will be the people with kids aged 0-4 outside Quebec. Failing to reject the null hypothesis of dominance will indicate that the cumulative distribution function of the skill index for the treatment group is always below than the one for the control, which means that the childcare policy affected the distributions of the skill requirements in the occupations in Quebec compared to the Rest Of Canada (ROC).

It would imply that the mean of the skills requirements in the occupations in Quebec is higher compared to the ROC. We do this exercise for two years: 1994 and 2004; we aim to identify any change in the distribution of the skill right before the starting of the policy and after the full implementation of it. In appendix C.1 we present results of a test for equality of the CDFs between the treatment and the control for both years. We found that there are statistically significant differences between the two CDFs, *therefore we estimate in this section the one sided differences and stochastic dominance to calculate the direction of the movement in the CDFs.* We follow a similar calculation for Lorenz dominance (second order dominance). In this case, failing to reject the null of dominance will indicate that the distribution of the skill index is more unequal in the treatment group than in the control. Table 3.1 shows the results for FOSD for a one sided hypothesis.

We cannot reject the hypothesis in 1994 and 2004 that the distribution of the analytical skill index for the treated group dominates the control. This indicates that there were

Table 3.1: First Order Stochastic Dominance Test

Skill Index	1994		2004	
	CV	KS	CV	KS
Analytical	0.006	0.013	0.001	0.004
	(0.322)	(0.065)	(0.862)	(0.634)
Physical	0.002	0.005	0.059	0.052
	(0.715)	(0.703)	(0.000)	(0.000)
Interpersonal	0.006	0.010	0.011	0.016
	(0.352)	(0.196)	(0.057)	(0.003)
Fine Motor	0.000	0.001	0.060	0.055
	(0.969)	(0.987)	(0.000)	(0.000)
Visual	0.002	0.003	0.053	0.051
	(0.776)	(0.851)	(0.000)	(0.000)

Bootstrap p-value with 1000 repetitions are in parenthesis.

significant base-line differences in the distributions of analytical skills among the workers who were eligible for the policy previous to its implementation in both groups. However, in figure 3.1 shows a stronger difference in 2004 than in 1994 which suggests that after the policy the CDF of this index moved to the right, increasing the difference between the two groups. Panel (a) of this figure shows that the CDF for the treated group is always within the two sided confidence interval, calculated using a CM statistic, for most of the values of the index except for the values slightly above 1 [2]. Panel (b,) on the other side, illustrates the conclusions of the p-values: there is a shift, in this case to the right, of the distribution of the CDF's for the treated group indicating a possible effect of the childcare policy over this skill index. In the next subsection we will identify the QTE for each of these difference to estimate the magnitude of these shifts.

The value of the tests for the Physical, Interpersonal, Fine Motor and Visual skills result in the same conclusion: we fail to reject the null of dominance for the period previous the implementation of the child care policy but we have enough information to reject this hypothesis for the year after the implementation. This result suggests that there was a movement of both CDFs. The direction of these movement are not identifiable directly from

[2] We also calculate the p-values for a equality test that can be found in the appendix C.1. We reject the null of equality for this index in both years, illustrating the need of a QTE to assess the effect in the different parts of the distribution.

the test itself, which is the reason that we rely in a graphical inspection to analyze these movements.

Figure 3.2 illustrates the changes for the Physical skill index. In 1994 the distribution for both groups overlap suggesting that there were no significant base-line differences between them. This does not happen in 2004 as there is a clear movement to the left of the treated group, which is consistent with the conclusion of the test. On the other hand, figure 3.3 panels (a) and (b) show the opposite effect. In 1994 the cumulative distribution of the Interpersonal skill index was almost the same for individuals in Quebec and in the Rest of Canada (ROC) with slightly differences at the top of the skill index. These differences in this part of the CDF vanish in 2004, where the difference now is around the middle value of the index. Again, this movement is consistent with the CM and KS tests for this ability.

Figure 3.3 panels (c) through (f) show the cumulative distributions for the Visual and Fine Motor skill index respectively. In the first case we see an almost equal CDF in 1994 with small differences around the mean of the index whereas in 2004 these differences persist though they are in the opposite direction. For the latter it seems graphically that in both years there are significant differences in the cumulative distribution of the Fine Motor Skill index. In 1994 the CDF of people in Quebec was below the one of the ROC in almost all the values of the index but at the top of the distribution; however, in 2004 the CDF for this group shifts upward the CDF of the control in almost every point instead, again, at the top part of the distribution.

Now we turn our attention to the Second Order Stochastic Dominance Test. Table 3.2 shows the result for this test. We cannot reject the null hypothesis of Lorenz dominance in 1994 for the Analytical and Interpersonal Index but there is enough evidence in the data to reject it for the rest of the skill indexes. These results are inverted in 2004 as there are enough evidence to reject the null hypothesis for these two indexes and not enough to reject for the Physical, Visual and Fine Motor Skill.

It seems that in 2004 the distribution of the Analytical and Interpersonal Skills were less unequal in Quebec after the full implementation of the policy. Figures 3.4 and 3.5 show the change. The movement is not big enough to be clearly seen in a graph for the Analytical

Table 3.2: Second Order Stochastic Dominance Test (Generalized Lorenz Dominance)

Skill Index	1994		2004	
	CV	KS	CV	KS
Analytical	0.000	0.000	0.005	0.009
	(0.743)	(0.766)	(0.000)	(0.000)
Physical	0.009	0.014	0.000	0.000
	(0.000)	(0.000)	(0.893)	(0.893)
Interpersonal	0.000	0.001	0.009	0.014
	(0.636)	(0.522)	(0.000)	(0.000)
Visual	0.010	0.016	0.000	0.000
	(0.000)	(0.000)	(0.929)	(0.934)
Fine Motor	0.007	0.010	0.000	0.000
	(0.000)	(0.000)	(0.827)	(0.789)

Bootstrap p-value with 1000 repetitions are in parenthesis.

skill index but the test is strong enough to identify it[3]. In the second case the move of the Lorenz curve to the left is more pronounced showing a less unequal distribution for this skill in Quebec after the policy. Figure C.2 illustrates the Lorenz graphs for the rest of the skill indexes. All of them show an increase in inequality in the distributions of skills from 1994 to 2004 in Quebec, results that are consistent with table 3.2 as we move from a point were treatment dominates control (rejecting the null, implying that Quebec is less unequal than ROC) to a point where controls dominates treatment (failing to reject the null, implying that Quebec is more unequal than ROC)[4].

So far we have presented the stylized facts on the distribution of skills before and after the policy by analyzing and testing first and second order stochastic dominance. Now we move to calculate the differences across all the quantiles to get a better picture of the total effect of the affordable child care policy in the skills in subsection 3.5.2.

[3]In the appendix C.1 we present the difference in the Lorenz curve between the treated and the control group to check in which quantiles the difference is the biggest.

[4]In general, rejecting the null does not implies that one group is less unequal than the other; for example, it could be the case that the Lorenz curves cross at some point. In this document, we can be certain of affirming this as from the graphs it is clear that the Lorenz curves are not crossing and the distribution of some indexes moved from a more unequal to a less unequal.

3.5.2 Quantile Treatment Effect

We split this subsection into two analysis. In the first one we estimate the QTE estimated without controlling for any covariates in 3.5.2 and in subsection 3.5.2 we estimate the QTE controlling for covariates. In general, the estimates in these tables should be interpreted as the difference in the skill index between the treated and the control groups in all the different deciles of the distribution. Positives values would mean that, for that particular decile, the people in Quebec work in occupations that require more of this skill than the control in terms of standard deviations from the mean of the skill distributions in the Canadian Work Force[5]. For example, suppose that for the median ($\tau = 0.5$) the QTE is 0.1. This mean that for the occupations that required the median skill (Analytical, Physical, etc), the individuals in Quebec were working in occupations that required 0.1 standard deviations more skills than the workers in the ROC.

QTEs With No Covariates

Table 3.3 shows the QTE for all the deciles of the distribution of the five different skill indexes. Several important findings can be seen. Let's focus our attention in the Analytical skill index; in 1994, that are the base-line differences between provinces, all the differences in the quatiles were positive but only were significant the values around the middle of the distribution as well as the top (deciles 4, 5, 6, 8 and 9). Take, for example, the estimation for the median. It says that in the occupations that require the median analytical skills in the work force of Canada, the workers in Quebec worked in occupations that required 0.08 standard deviations more than in the rest of Canada. It also means that more people in Quebec were working in occupations that require more analytical skills in the median of the distribution compare to the comparable occupations outside this province. Moving our attention to 2004 we can see that these differences increased in the middle but are reduced at the top. At the median, the difference increased to 0.108 whereas at the 90th percentile the difference went down to 0.001, a nine times reduction.

For the Physical skill index, deciles 1, 2, 4, 6 are significant different from zero. In the

[5]Recall that the skill indexes are normalized such that the mean of it, which is zero, is the skill required for the mean occupation in the Canadian Labor Force

bottom of this distribution there are positive differences while in the median the difference is negative. In 2004, however, there is an entirely different picture. In all the deciles, the value of the QTE is negative. It is significant around the median of the distribution as well as the top. In the 5th decile, the estimated effect is -0.24, meaning that less people in Quebec were working in occupations that require physical skills in the median of the distribution compare to the comparable occupations outside this province[6].

The interpersonal skill index tells a similar story to the analytical one. All the differences in the quantiles were positive in 1994 as well as for 2004. At the median of the distribution there is a change in the QTE from 0.067 to 0.128 standard deviations. The Visual and the Fine Motor skill indexes show a change from positive to negative in the estimation for most of the deciles. There is a significant positive difference of 0.068 standard deviation in the 20th percentile for the visual index in 1994 while for 2004 this difference reverts its sign to -0.082. For the median in 1994 the difference is not statistically significant from zero but it is for 2004 which is -0.015. At the top, in the ninth decile, the difference remains negative but higher, moving form -0.021 to -0.107. On the Fine Motor skill side, the difference in the bottom was positive in 1994 given that for the second decile this is 0.035 but after the policy this was -0.099. In the median the QTE changes from 0.181 to -0.056 both significant. On the other side, at the top, in the 90th percentile, in 1994 the difference is positive in 0.004 standard deviation turning to negative in 2004 though it is not significant.

QTEs With Covariates

Table 3.4 shows the estimate of the QTE controlling for a set of covariables[7]. The estimation for the bottom deciles of Analytical skill index in 1994 are not significant. These go in line with the findings in the last subsection although the differences in the quantiles for the 60th and 70th percentiles are negative. The effects in the top of the distribution are still significant and positive after controlling for covariates. In 2004, on the other side, all the

[6]Note that these QTEs match the results from the Stochastic Dominance tests. We should expect that, if the distribution for a given index in Quebec stochastic dominates the distribution of that index for the ROC, the QTEs will be positive for most of them and negative in the opposite case.

[7]We include as controls the total hours worked by the individual, the number of kids below aged 4 and dummies that control for gender, whether the household is a two parent families and whether the individual is in a full time or a part time job

treatment effects are positive excluding the ninth decile. In the median of the distribution, the estimation is the same than 1994. For the sixth and seventh deciles, these treatments are positive and significant whereas at the top of the distribution the difference is -0.018 though it is not significant different from zero.

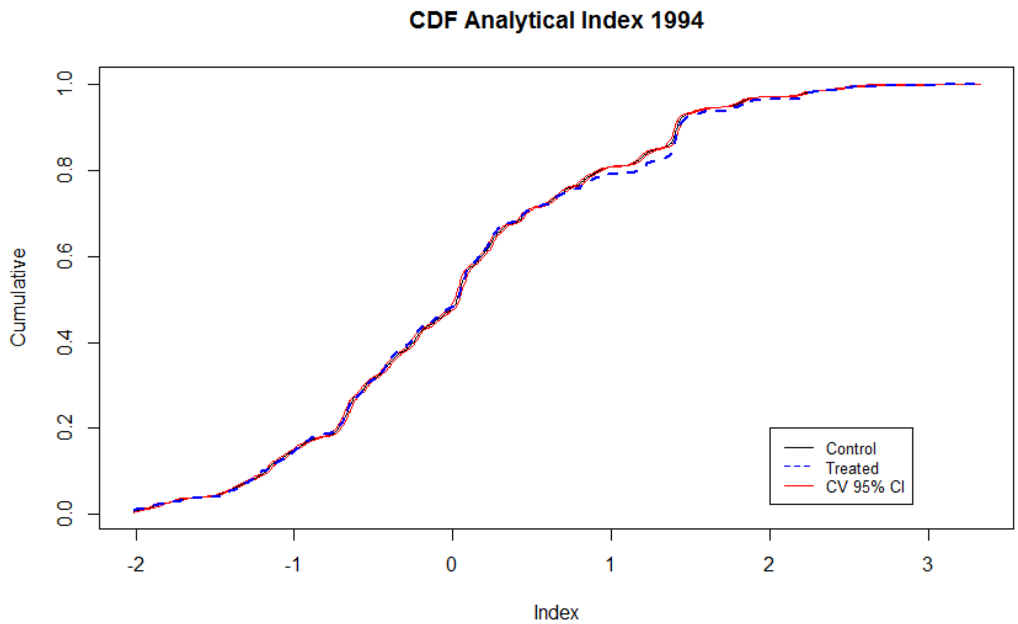
Moreover, the Physical skill index when controlling for covariates shows a different picture in 1994 compared to the results in subsection 3.5.2 as all the differences in the quantiles are positive excluding the 60th percentile. Most of these differences are non significant excepting the estimations for the deciles number 1,2,4 and 6. On the contrary, in 2004 all of the treatment effects are negative or zero. The biggest effect was at the median with a difference of -0.204 standard deviations, the same estimation for this same quantile in table 3.3. Similar results can be seen for the Visual skill index. In 1994 all the estimations were positive except for the seventh and eighth deciles with only significant estimations in the 20th, 30th and 40th quantiles whereas in the upper part of the distribution the significant effect is in the 70th percentile. However, in 2004, all the estimations of the treatment effects are negative and significant except for the median. The biggest difference is at the top, in the 80th percentile with a difference of -0.239 standard deviations.

Calculations for the Fine Motor skill index follow the same pattern as before; all the estimates of the difference before the policy were positive. In 1994 the biggest effect was at the median, with a base-line difference of 0.199 whereas for 2004 the treatment effects are negative, where the biggest difference is at the 80th percentile with a treatment effect of -0.151. On the side of the Interpersonal skill index, it seems that, for 1994, the difference bounce between positive and negative values around the whole distribution. the biggest positive effect is at the upper tail, with a difference of 0.089 and the biggest negative effect is at the median although this estimation is not significant. Finally, in 2004, the estimations of the treatment effects are positive in most of the deciles. The biggest effect is at the bottom with a difference of 0.099 in the 30th quantile[8].

[8]In appendix C.3 we present graphs of the QTEs with a 95% confidence intervals for both, the conditional and unconditional quantiles.

Figure 3.1: CDF Analytical Index 1994 and 2004

(a) CDF Analytical Index 1994



(b) CDF Analytical Index 2004

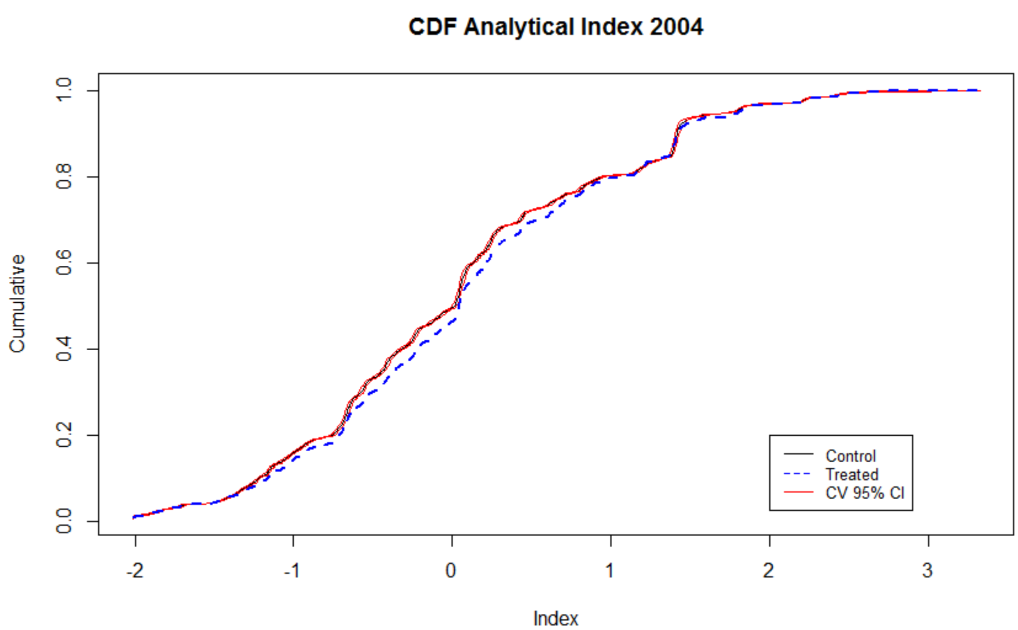
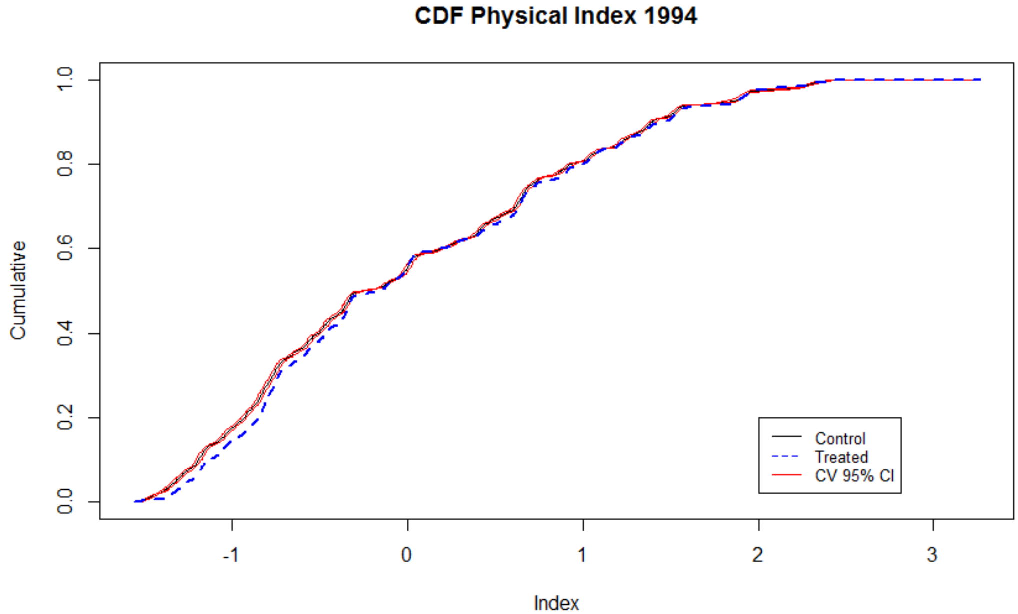


Figure 3.2: CDF Physical Index 1994 and 2004

(a) CDF Physical Index 1994



(b) CDF Physical Index 2004

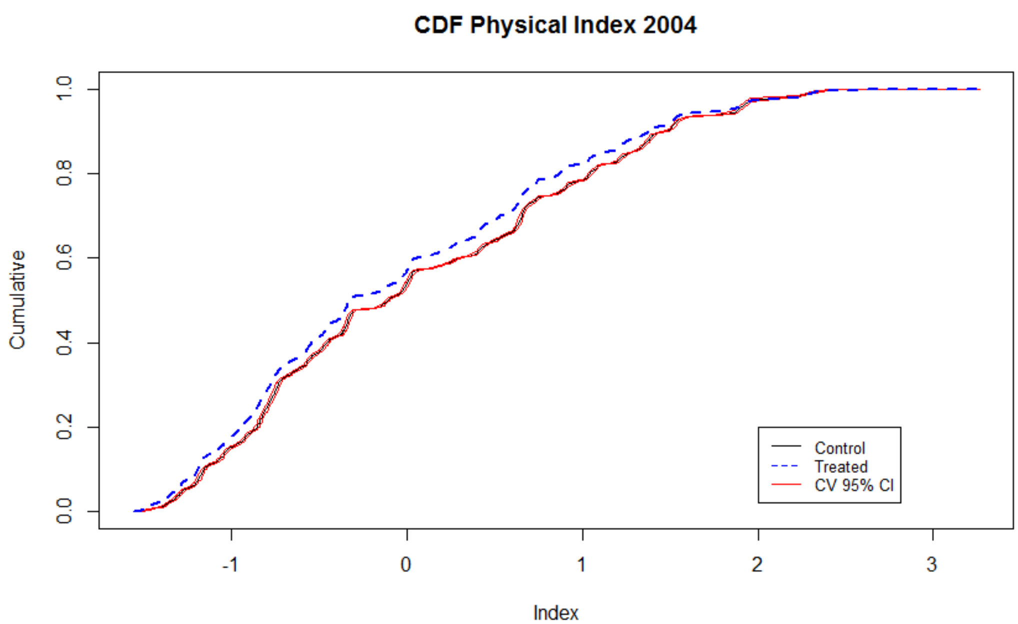
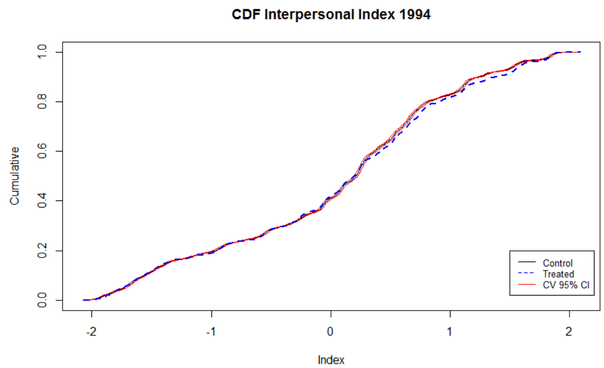
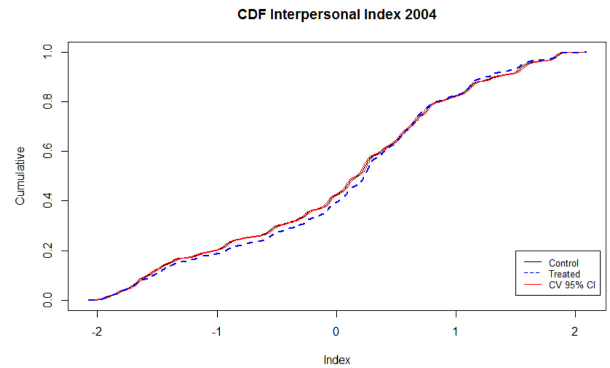


Figure 3.3: CDF Interpersonal, Visual and Fine Motor Skill Indexes 1994 and 2004

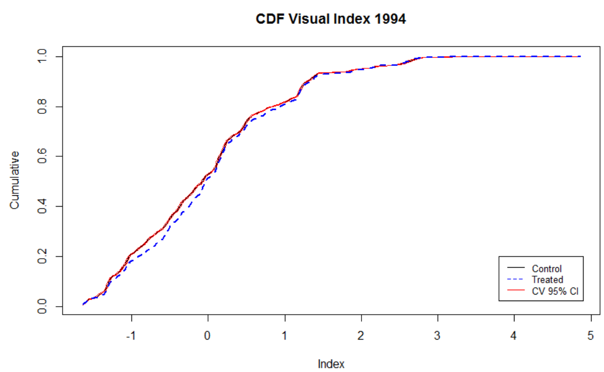
(a) CDF Interpersonal Index 1994



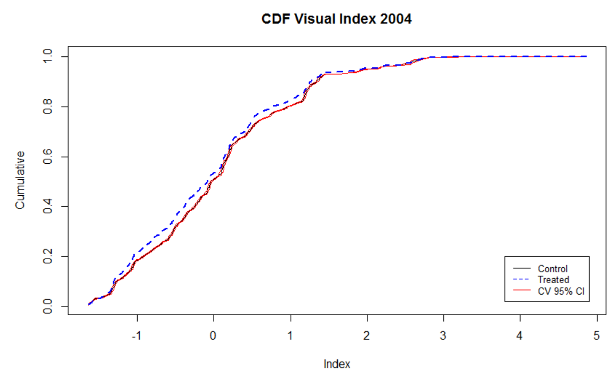
(b) CDF Interpersonal Index 2004



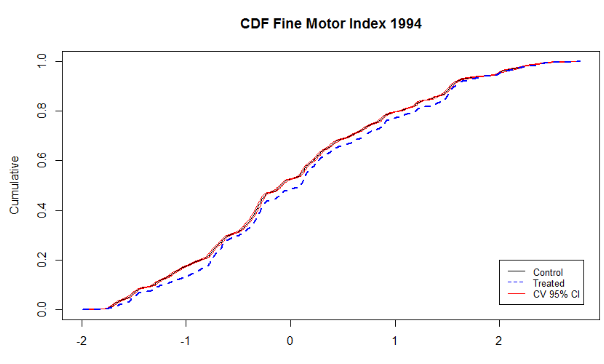
(c) CDF Visual Index 1994



(d) CDF Visual Index 2004



(e) CDF Fine Motor Index 1994



(f) CDF Fine Motor Index 2004

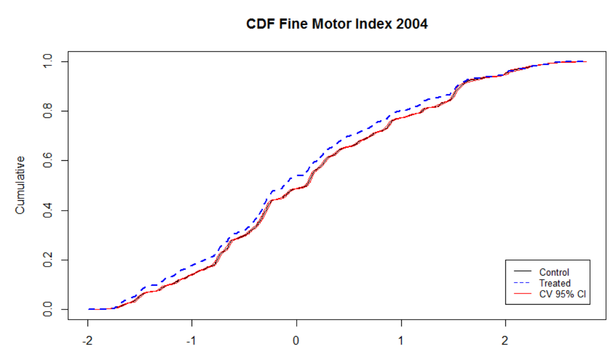
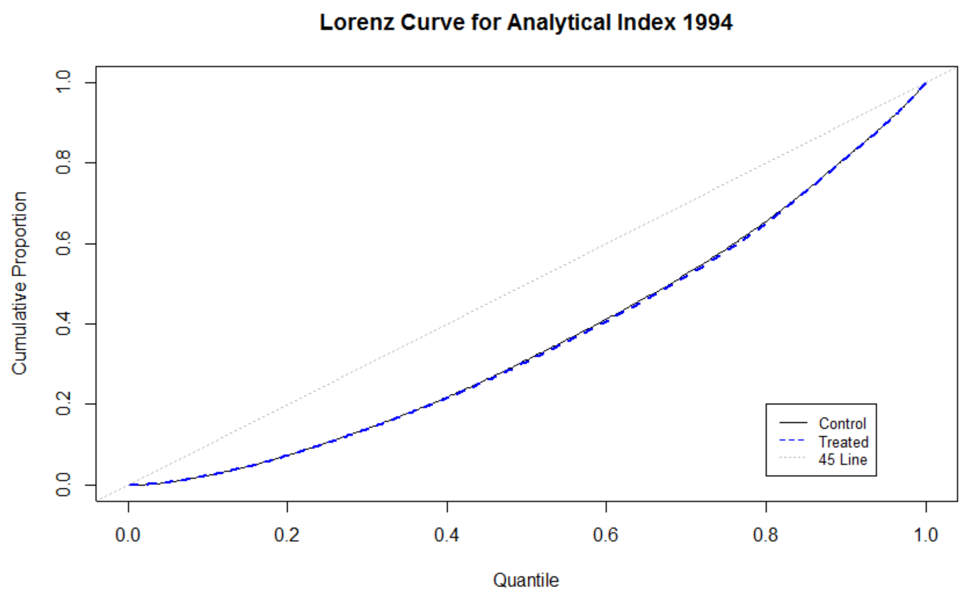


Figure 3.4: Lorenz Curves for Analytical Index 1994 and 2004

(a) Lorenz Analytical Index 1994



(b) Lorenz Analytical Index 2004

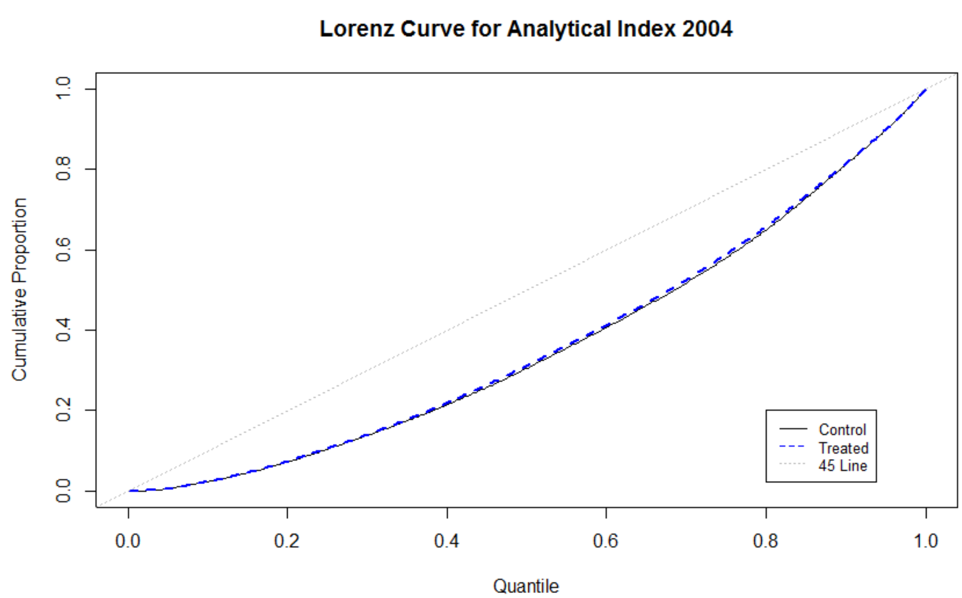
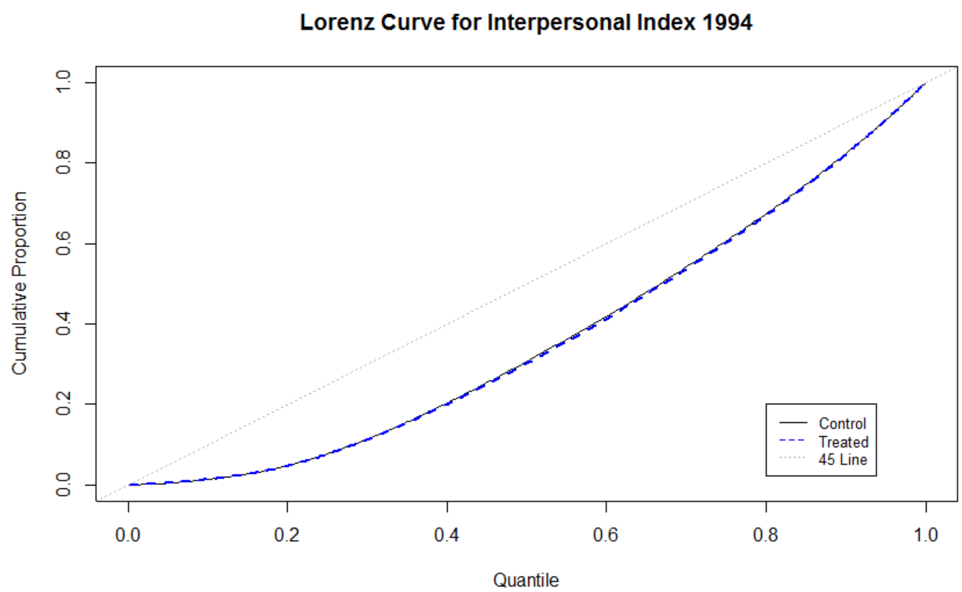


Figure 3.5: Lorenz Curves for Interpersonal Index 1994 and 2004

(a) Lorenz Interpersonal Index 1994



(b) Lorenz Interpersonal Index 2004

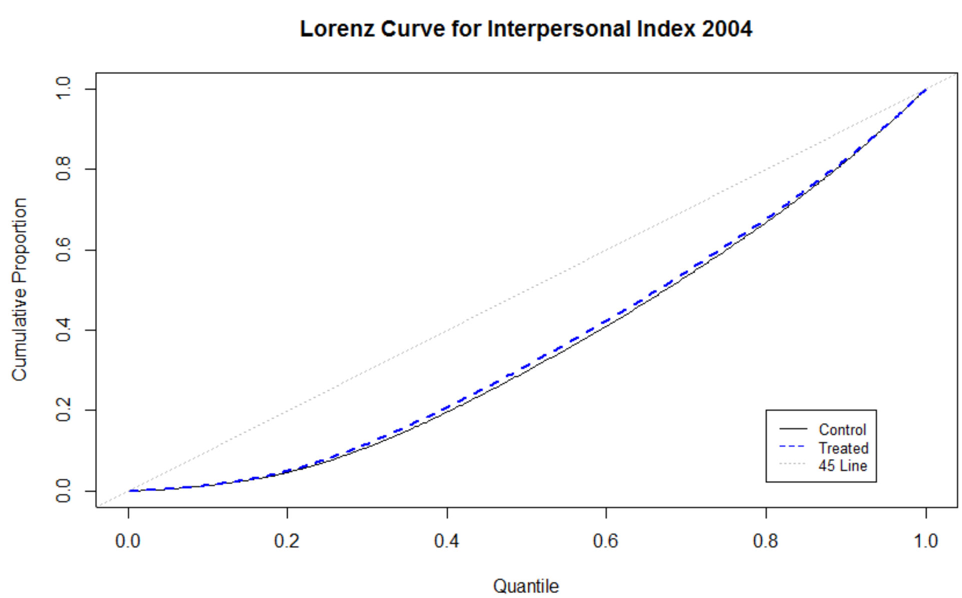
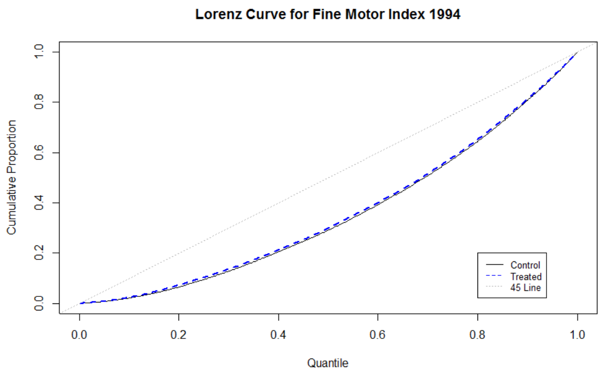
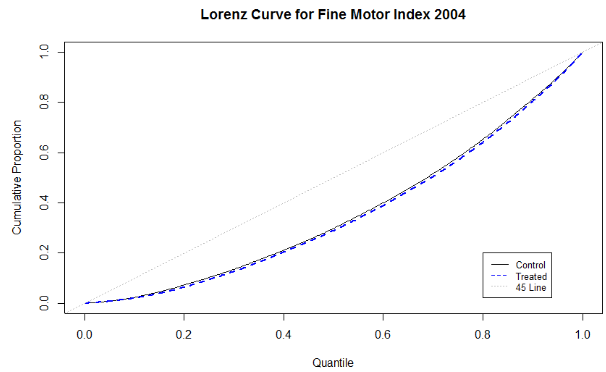


Figure 3.6: Lorenz Curves for the Fine Motor, Visual and Physical Skill Index 1994 and 2004

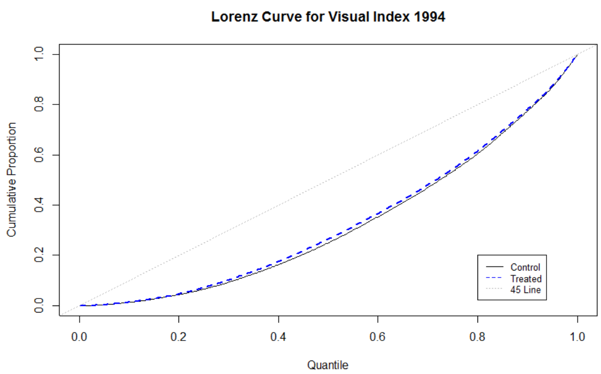
(a) Lorenz Fine Motor Index 1994



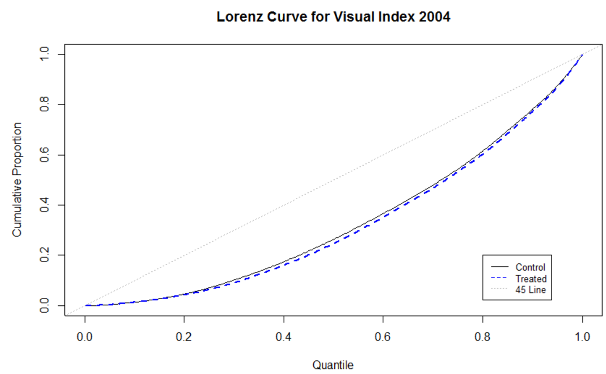
(b) Lorenz Fine Motor Index 2004



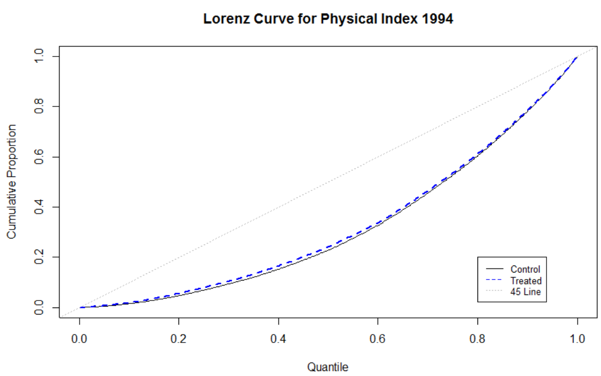
(c) Lorenz Visual Index 1994



(d) Lorenz Visual Index 2004



(e) Lorenz Physical Index 1994



(f) Lorenz Physical Index 2004

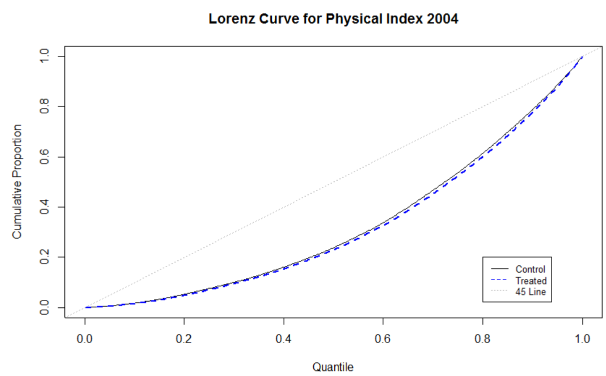


Table 3.3: Quantile Treatment Effect With No Covariates

Skill Index	1994									2004								
	τ									τ								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Analytical	0.024	0.027	0.011	0.068	0.080	0.050	0.001	0.272	0.009	0.078	0.035	0.104	0.119	0.108	0.146	0.127	0.152	0.001
	(0.021)	(0.009)	(0.015)	(0.012)	(0.005)	(0.019)	(0.004)	(0.029)	(0.001)	(0.007)	(0.019)	(0.022)	(0.005)	(0.010)	(0.008)	(0.047)	(0.069)	(0.003)
Physical	0.039	0.073	0.007	0.027	-0.052	-0.115	-0.003	-0.052	0.004	-0.012	-0.007	-0.036	-0.067	-0.240	-0.305	-0.125	-0.187	-0.069
	(0.013)	(0.005)	(0.006)	(0.005)	(0.042)	(0.039)	(0.002)	(0.045)	(0.044)	(0.001)	(0.013)	(0.010)	(0.003)	(0.006)	(0.038)	(0.011)	(0.008)	(0.013)
Interpersonal	0.003	0.109	0.142	0.002	0.067	0.115	0.105	0.145	0.103	0.012	0.132	0.195	0.086	0.128	0.104	0.093	0.071	-0.007
	(0.005)	(0.019)	(0.038)	(0.002)	(0.020)	(0.010)	(0.007)	(0.023)	(0.034)	(0.009)	(0.015)	(0.023)	(0.008)	(0.002)	(0.009)	(0.010)	(0.019)	(0.016)
Visual	0.014	0.068	0.057	0.101	0.015	0.000	-0.036	-0.019	-0.021	-0.034	-0.082	-0.096	-0.030	-0.015	-0.069	-0.057	-0.244	-0.107
	(0.010)	(0.023)	(0.003)	(0.007)	(0.016)	(0.012)	(0.016)	(0.023)	(0.009)	(0.003)	(0.004)	(0.008)	(0.009)	(0.005)	(0.000)	(0.012)	(0.039)	(0.004)
Fine Motor	0.058	0.035	0.143	0.044	0.181	0.028	0.114	0.114	0.004	-0.032	-0.099	-0.038	-0.003	-0.056	-0.059	-0.135	-0.125	-0.014
	(0.024)	(0.001)	(0.024)	(0.008)	(0.013)	(0.011)	(0.024)	(0.012)	(0.001)	(0.037)	(0.012)	(0.029)	(0.003)	(0.008)	(0.018)	(0.034)	(0.043)	(0.016)

Table 3.4: Quantile Treatment Effect With Covariates

Skill Index	1994									2004								
	τ									τ								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Analytical	-0.029	0.000	0.001	-0.017	0.015	-0.031	-0.022	0.234	0.018	0.041	0.000	0.064	0.046	0.015	0.049	0.073	0.100	-0.018
	(0.028)	(0.006)	(0.011)	(0.020)	(0.004)	(0.012)	(0.009)	(0.015)	(0.008)	(0.012)	(0.007)	(0.019)	(0.006)	(0.001)	(0.006)	(0.044)	(0.070)	(0.013)
Physical	0.040	0.073	0.003	0.091	0.006	-0.056	0.000	0.004	0.049	-0.004	-0.006	-0.029	0.000	-0.204	-0.211	-0.124	-0.172	-0.001
	(0.017)	(0.005)	(0.006)	(0.004)	(0.043)	(0.027)	(0.003)	(0.057)	(0.043)	(0.001)	(0.010)	(0.013)	(0.008)	(0.010)	(0.030)	(0.019)	(0.012)	(0.006)
Interpersonal	-0.008	0.000	0.055	-0.013	-0.014	0.042	0.074	0.085	0.089	-0.008	0.000	0.099	0.075	0.045	0.031	0.055	0.013	-0.015
	(0.011)	(0.008)	(0.039)	(0.014)	(0.009)	(0.013)	(0.009)	(0.024)	(0.035)	(0.014)	(0.003)	(0.025)	(0.010)	(0.007)	(0.009)	(0.008)	(0.020)	(0.010)
Visual	0.013	0.108	0.072	0.116	0.016	0.000	-0.048	-0.018	0.000	-0.035	-0.068	-0.095	-0.032	-0.001	-0.072	-0.065	-0.239	-0.109
	(0.010)	(0.025)	(0.006)	(0.013)	(0.015)	(0.004)	(0.021)	(0.022)	(0.009)	(0.005)	(0.005)	(0.010)	(0.010)	(0.005)	(0.000)	(0.018)	(0.031)	(0.006)
Fine Motor	0.080	0.118	0.152	0.044	0.199	0.056	0.127	0.113	0.000	-0.015	-0.077	0.000	0.000	-0.042	-0.031	-0.070	-0.151	-0.006
	(0.031)	(0.005)	(0.024)	(0.009)	(0.017)	(0.011)	(0.024)	(0.029)	(0.001)	(0.039)	(0.032)	(0.026)	(0.003)	(0.009)	(0.015)	(0.037)	(0.042)	(0.015)

3.6 Final Comments

We use newly developed methods to test for stochastic and Lorenz dominance to assess whether the distribution of skill requirements in occupations in Quebec is different before and after the policy relative to changes in the distribution of skills in the Rest of Canada. We complement this analysis by calculating Quantile Treatment Effects using a propensity score re-weighting technique developed by Firpo (2007) to measure these differences across the distributions. In the context of this paper, dominance will tell us that individuals in the group that dominates work on occupations that require more skills than the other. This technique allows us to identify changes in the skill requirements in occupations in a potentially revealing way and correlate these changes with policy changes.

The value of the stochastic dominance tests for the Physical, Interpersonal, Fine Motor and Visual skills result in the same conclusion: we fail to reject the null of dominance for the period previous the implementation of the child care policy but we have enough information to reject this hypothesis for the year after the implementation.

Our results suggest that the distribution of the interpersonal, physical, visual and fine motor skills index in Quebec stochastically dominates the distribution of skills in the rest of Canada in 1994, whereas in 2004 the dominance is reversed. However, the distribution of the analytical skill index in Quebec dominates the one for the rest of Canada in both years. The estimation of Quantile Treatment Effects strengthens these results by showing that the largest changes in the analytical skill index happened in occupations at the median ability level of the Canadian Labour force.

These results suggest that there was a movement of all CDFs. This means that the individuals in Quebec with childcare-aged children were working on occupations that require more of these abilities in 1994 than similar parents in the rest of Canada, while the opposite is true in 2004. This is an interesting result as it could suggests that the affordable childcare policy potentially helped to move the distribution of workers across occupations, decreasing the amount of people working on these jobs. Moreover, these occupations are associated with less job quality and are less paid on average. Note, however, that these are not causal effects, as we can only compare two years for two different groups.

To the best of our knowledge, we are the first to offer descriptive evidence of the impact of the Quebec childcare policy on the whole distribution of job skills. This is a first step to estimate distributional causal effects associated with this policy. A natural extension for this paper is to use a Quantile difference-in-differences estimation to estimate the total effect of the affordable childcare policy in the skill requirements comparing Quebec and the Rest of Canada.

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APPENDICES

Appendix A

Appendix for Chapter 1

A.1 The COPERT 4 Model

The reasons for choosing the COPERT 4 model in this study are as follows: (1) The COPERT 4 model is the newest version of the COPERT III model with updated emission factors for different vehicle types, calculation methods of these factors as well as pollutant allocation ratios, which enables the simulation to more closely reflect real world conditions. (2) The COPERT 4 model adopts similar vehicle test conditions and vehicle emission standard systems in China and can be used to study vehicle emissions with different emission standards. (3) The parameters required by the COPERT 4 model are relatively simple and applicable to countries with different emission standards and sparse traffic data. (4) The COPERT4 model can calculate the amount of conventional and unconventional gas pollutants and heavy metal pollutants of hundreds of vehicle types while also calculating their fuel consumption, thereby more fully reflecting the vehicle's pollutant discharge conditions.

A.1.1 Emission Factor Calculation

When the COPERT 4 model is used to calculate an emission factor, the parameters to be inputted are roughly divided into: (1) traveling condition data such as fleet composition, mileage, driving proportion and average driving speed; (2) meteorological parameters such as the highest, lowest and monthly average temperature, air humidity and air pressure; (3) fuel parameters such as the annual consumption of motor gasoline and diesel or their respective parameters of the nature. The values of these parameters ultimately determines emissions factors which are crucial in the study. The following subsections explains the parameters that we used.

Main Parameters

Classification

In the COPERT 4 model, vehicles are classified into PC (passenger car), LCV (light commercial vehicle), HDV (heavy-duty vehicle), MC (Motorcycle), Mopeds and Buses. Vehicles can also be divided into fuel types such aspetrol (leaded and unleaded), diesel, natural gas, liquefied petroleum gas, biodiesel and bioethanol. According to the emission standards, vehicles are classified into ECE15/00-01, ECE15/02, ECE15/03, ECE15/04, Improved conventional, Open loop Conventional, Eurol-91/441/EEC, Euro2-94/12/EC, Euro3-98/9/EC Stage2000, Euro4-98 Stage2005, Euro5-EC715/2007, Euro6-EC715/2007, and Euro6c-EC715/2007.

Given the displacement, vehicles will be divided into 4 categories for gasoline based cars: small displacement vehicles composed of cars with engine size less than 0.8 liters, medium small vehicles with engine size between 0.8- 1.4 liters, medium vehicles with engine size between 1.4-2.0 liters and big cars for those with displacement more than 2.0 liters. We also subdivide the roads into 3 types: urban area, suburban area and highway. In the COPERT4 model, vehicle are fully classified covering all European modes.

Given their engine displacement, vehicles are divided into 4 categories for gasoline based cars: small displacement vehicles composed of cars with engine sizes less than 0.8 liters, medium small vehicles with an engine size between 0.8- 1.4 liters, medium vehicles with an engine size between 1.4-2.0 liters and big cars for those with engine displacements greater than 2.0 liters. We also subdivide the roads into 3 types: urban area, suburban area and highway. In the COPERT4 model, vehicles are fully classified covering all European modes.

In 1983, China started to promulgate and implement its first domestic vehicle emission standards and regulations. In 1999, it formulated the emission standard GB14761- 1999 for automobiles according to the Euro I standards, which is called ”the national 1 standard”.

Nowadays, China's emission standards are all formulated with reference to the European standard system, but the implementation time is relatively different than in Europe. The national 2 standard, the equivalent of the European II standard, began to be implemented on July 1st of 2005. From July 1st of 2007, the implementation of the third phase of the national vehicle emission standards started, the national 3 standard. In order to better control the pollution of motor vehicles, the state implemented the fourth phase of the national emission standards in 2011, namely national 4 standards. And in 2013, Beijing began to implement the fifth stage of more stringent national vehicle emissions, namely the national 5 standard. Since then, China's motor vehicle emission standards and regulations are essentially on par with international standards.

To estimate total emissions of passenger cars in all Chinese provinces from 2003 to 2013, vehicles should be classified according to the type of passenger cars in the COPERT 4 model as well as stocks of passenger cars included in the database of the National Transportation Administration of China. To achieve this, we depart from the registration of new cars included in this data set. We determine which emission control standard should be assigned and then calculate the proportion of cars that has this standard in subsequent years. Based on table A.1 and taking into account the factor of sales lag time, we identified newly registered gasoline and diesel cars from 2003 to 2005, gasoline and diesel cars from 2006 to 2008, diesel cars from 2009 to the present, gasoline cars from 2009 to 2012, and gasoline cars from 2013 to the present that are the national 1 standard, national 2 standard, national 3 standard, and national 4 standard. Vehicles are then divided into sub-categories based on fuel type, engine displacement and emission control standards (Table A.2).

Total emission by pollutant will be the linear sum between the emissions of gasoline and diesel based cars. We need to aggregate these emissions into two groups that have been discussed before: small engine size (cars with displacement less or equal than 3 liters) and big engine size (cars with displacement bigger than 3 liters). To this end, we check what is the proportion of cars with engine technology (EURO 1,2,3 or 4) that are bigger than 2 liters and multiply this fraction by the total emissions of a given pollutant in this same group to calculate the total emissions by the bigger cars. Small cars emissions is the difference between total emissions by pollutant (sum of emissions of all standards) and the emissions of big cars. The following formula explains how we calculate total emissions by pollutant in the two groups

$$Emissions_{PH} = s_{E1}\left(Gas_{(>2,E1,P)} + Diesel_{(>2,E1,P)}\right) + s_{E2}\left(Gas_{(>2,E2,P)} + Diesel_{(>2,E2,P)}\right) + s_{E3}\left(Gas_{(>2,E3,P)} + Diesel_{(>2,E3,P)}\right) + s_{E4}\left(Gas_{(>2,E4,P)}\right) \tag{A.1}$$

$$Emissions_{PL} = Total_P - Emisssions_{PH} \tag{A.2}$$

where P is a given pollutant, > 2 represent the cars bigger than 2 liters that could be either from Gasoline or Diesel, $E1..E4$ represents technology Euro 1, 2, 3 or 4 respectively. Then, in this case s_{E1} is the proportion of cars with engine size bigger than 3 liters with engine technology Euro 1, $Gas_{(>2,E1,P)}$ is the total emissions of a pollutant P of a gasoline based car with engine size bigger than 2 and technology standard Euro 1. H, L are high or low engine size. Also note that:

$$Total_P = \sum_i \sum_j \sum_s Pollutant_{pijs}$$

where i is the type of car (gasoline or diesel), j is the technology (Euro 1,2,3,4) s is the size (0.8-2). Thus, this is the linear sum of emissions by each pollutant.

Table A.1: Implementation Schedule of China's Vehicle Emission Standards

Fuel type	National 1 Euro I	National 2 Euro II	National 3 Euro III	National 4 Euro IV	National 5 Euro V
gasoline	2000.7	2005.7	2007.7	2011.7	2013.7
diesel	2000.7	2005.7	2007.7		

Source: The authors

Table A.2: Classification of Passenger Cars by Fuel Type, Displacement and Emission Standards

Fuel	Engine Size	Technology
Gasoline	Gasoline <0.8 L	PC Euro 4 - 98/69/EC Stage2005
	Gasoline 0.8 - 1.4 L	PC Euro 1 - 91/441/EEC
	Gasoline 0.8 - 1.4 L	PC Euro 2 - 94/12/EEC
	Gasoline 0.8 - 1.4 L	PC Euro 3 - 98/69/EC Stage2000
	Gasoline 0.8 - 1.4 L	PC Euro 4 - 98/69/EC Stage2005
	Gasoline 1.4 - 2.0 L	PC Euro 1 - 91/441/EEC
	Gasoline 1.4 - 2.0 L	PC Euro 2 - 94/12/EEC
	Gasoline 1.4 - 2.0 L	PC Euro 3 - 98/69/EC Stage2000
	Gasoline 1.4 - 2.0 L	PC Euro 4 - 98/69/EC Stage2005
	Gasoline >2.0 L	PC Euro 1 - 91/441/EEC
	Gasoline >2.0 L	PC Euro 2 - 94/12/EEC
	Gasoline >2.0 L	PC Euro 3 - 98/69/EC Stage2000
	Gasoline >2.0 L	PC Euro 4 - 98/69/EC Stage2005
Diesel	Diesel <1.4 L	PC Euro 4 - 98/69/EC Stage2005
	Diesel 1.4 - 2.0 L	PC Euro 1 - 91/441/EEC
	Diesel 1.4 - 2.0 L	PC Euro 2 - 94/12/EEC
	Diesel 1.4 - 2.0 L	PC Euro 3 - 98/69/EC Stage2000
	Diesel >2.0 L	PC Euro 1 - 91/441/EEC
	Diesel >2.0 L	PC Euro 2 - 94/12/EEC
	Diesel >2.0 L	PC Euro 3 - 98/69/EC Stage2000

Source: The authors and COPERT 4 Model

Mileage and driving ratio

The COPERT4 model requires input of the annual cumulative mileage of vehicles as well as the proportion of vehicles traveling on urban roads, rural roads and highways, all of which directly affect the calculation of the final emission factors. However, since this data cannot be directly obtained from official statistics, reasonable estimations are supposed to be made based on relevant statistics and surveys.

Considering the relevant research results, the average annual mileage of passenger cars in this study is 18,000km, and the average total mileage of passenger cars is 120,000km. The proportion of vehicles driving in urban areas, rural areas and on highways can be estimated as follows: using the data on roads in China's statistical year from 2002, we take the proportion of urban roads and provincial highways in the total number of kilometers traveled as the proportion of vehicles traveling on urban areas and high-ways, then the proportion of suburbs can be calculated also. The results show that: (1) The proportion of driving in urban areas, rural areas and on highways for the 4 municipalities, namely Beijing, Tianjin, Shanghai and Chongqing, is 50%, 10% and 40%; (2) The proportion of traffic from other provinces is 40%, 20% and 40% respectively.

Average speed

The average speed is the basis for the COPERT 4 model operation. According to the related research results and the traffic speed regulations from the China Transporta- tion Department, the average speeds of passenger cars on urban roads, rural roads and highways are 30km/h, 55km/h and 90km/h respectively.

A.1.2 Other Parameters

Climate parameters

Climate parameters include the highest monthly average temperature, the lowest monthly temperature, air humidity and pressure in all provinces, as obtained from the China Meteorological Data website http://data.cma.cn/data/.

Fuel parameters

Fuel parameters include the vapor pressure of fuel and the content of various components in the fuel. The vapor pressure of a gasoline vehicle is obtained at 74kPa in winter (September to February) and 88kPa in summer (March to August) according to the relevant Chinese fuel standards. Furthermore, gasoline is unleaded (lead content is less than 0.013g/L), and sulfur content of gasoline and diesel is 0.02% and 0.05% respectively.

Average travel length

Average travel length is the average distance traveled by a car during one operation. The COPERT 4 default travel length is 12 km.

Load and slope

Both vehicle load and road slope have an impact on vehicle emission factors. This study uses a model default value, that is to say that the vehicle load is 50% regardless of slope. The calculation of the emission factor in the COPERT4 model mainly includes 7 modules, each of which is used to calculate specific emission factors, including mileage decay, fuel effect, thermal emission factor, cold emission factor, volatile emission factor, air conditioning service factor and CO2 emission factor from lubricating oil. After the above parameters are included into the model, and the parameters that were not mentioned above are taken as the default values of the model, the pollutant emission factors of various types of passenger cars in each province can be calculated.

A.1.3 Emissions calculation of passenger cars

Based on formula 1.1, in order to calculate the emissions of various pollutants of different types of passenger cars, in addition to calculating the integrated emission factors of these pollutants, the annual stocks of each type of passenger cars are essentially required. Calculated as follows:

Ownership of a certain car type

The calculation of a certain type of vehicle ownership is given by formula A.3

$$C_{i,t} = C_{i,t-1} + N_{i,t} - O_{i,t} \tag{A.3}$$

Where $C_{i,t}$ represents the stocks of car type i in year t; $C_{i,t-1}$ is the stocks of car type i in year $t-1$; $N_{i,t}$ is the sales of car type i in year t, which can be approximately by the number of yearly new registered passenger cars, which comes from the passenger car database of the China Transportation Administration; $O_{i,t}$ states the number of scrapped car of type i in year t.

According to the car types in Table A.2, the total number of the new car registrations in each year is divided into the number of cars in every sub-category, such as the number of new registered cars for a certain type i in 2003. After obtaining the provincial stocks of passenger cars at the end of 2002 from the China Statistics website and using some reasonable assumptions, the stocks of passenger cars in each province in 2002 will be decomposed into the stocks of all types of cars, that is $C_{i,2002}$.

In this process, the following assumptions were made: (1) The stock structure of each type of passenger car in each province in 2002 is equal to the proportion of newly registered passenger cars of various types in each province in 2003; (2) Scrapped cars are zero, that is $O_{i,t} = 0$. Since we only analyze 11 years, and the average lifetime of a passenger car is 12 to 14 years, it is reasonable to assume that the ownership of all types of passenger vehicles in 2002 plus the number of newly registered passenger cars of various types in 2003 are the stocks of all types of passenger cars for 2003. Then, by induction, the stock of each mode in each year can be calculated. (3) As there is no newly registered passenger cars data about Xizang in the database in 2003 and 2004, the numbers of newly registered passenger cars have to be calculated based on the car stocks data that can be retrieved from the Statistical Information website of China. Also, it is assumed that the proportion of newly registered passenger cars in Xizang in 2003 and 2004 is consistent with the proportion of different car types in Xinjiang.

Finally, the passenger car database lacks the types of fuel (mainly gasoline and diesel) of passenger cars from 2003 to 2007. By using the average diesel vehicle share from 2008 to 2013, the share of diesel cars from 2003 to 2007 is set as follows: Almost all passenger cars with no more than 0.8 liters displacement are gasoline cars, meanwhile, diesel cars accounted for 0.4% to 0.6% of the total cars with engine displacements above 0.8 liters. Based on the above assumptions and formula A.3, the ownership of all types of cars in all provinces, $C_{i,t}$, can be calculated.

After the integrated emission factors, the number of passenger cars and the annual average mileage are substituted into formula (1), the emissions inventory with respect to 31[1] provinces, various car types and various emissions such as CO, NOx, NO, NMVOC, VOC, PM2.5, PM10 and PM (exhaust) are then calculated.

A.2 Clustered Bootstrapped p-values an t-stats

Table A.3: Clustered Bootstrapped p-values and t-statistics for table 1.5

Pollutant		(I)	(II)	(III)
VOC	t-stat	-5.8845	-5.2834	-5.7822
	p-value	0.0000	0.0000	0.0000
PM10	t-stat	-6.2515	-2.7759	-6.0266
	p-value	0.0000	0.0018	0.0000
PM	t-stat	-6.0225	-2.1132	-5.8130
	p-value	0.0000	0.0143	0.0000
NOX	t-stat	-5.8021	-1.8960	-5.6110
	p-value	0.0000	0.0259	0.0000
NO	t-stat	-5.8016	-1.8814	-5.6105
	p-value	0.0000	0.0268	0.0000
NMVOC	t-stat	-5.7992	-5.5061	-5.7045
	p-value	0.0000	0.0000	0.0000
CO	t-stat	-5.7164	-5.9176	-5.6180
	p-value	0.0000	0.0000	0.0000
PM25	t-stat	-6.2343	-2.7142	-6.0105
	p-value	0.0000	0.0022	0.0000

A.3 Air Quality Index

The air pollution index is divided into seven levels which correspond to seven air quality levels. Larger values of the index, indicate that the pollution is more serious and the influence

[1]The province of Xizang lacks information about the registration of cars and data about unemployment rate for 2003 and the period 2006-2008 which makes us unable to calculate emissions for these years for this province

Table A.4: Clustered Bootstrapped p-values and t-statistics for table 1.6

Pollutant		(I)	(II)	(III)	(IV)
VOC	t-stat	-2.8553	-2.9476	-0.7155	-0.7551
	p-value	0.0058	0.0021	0.7289	0.7289
PM10	t-stat	-4.8293	-2.2920	4.2926	4.5300
	p-value	0.0000	0.0362	0.0000	0.0000
PM	t-stat	-4.1534	-3.5179	-2.4767	-2.6136
	p-value	0.0000	0.0000	0.0001	0.0001
NOX	t-stat	-2.9912	-3.5298	-2.0736	-2.1882
	p-value	0.0060	0.0001	0.0002	0.0002
NO	t-stat	-2.9920	-3.5173	-2.0232	-2.1351
	p-value	0.0058	0.0001	0.0003	0.0003
NMVOC	t-stat	-2.6047	-2.9680	-1.0213	-1.0778
	p-value	0.0130	0.0018	0.3095	0.3095
CO	t-stat	-3.3074	-1.9121	3.3363	3.5207
	p-value	0.0011	0.0668	0.0010	0.0010
PM25	t-stat	-4.7779	-2.3865	3.9687	4.1881
	p-value	0.0000	0.0269	0.0001	0.0001

Table A.5: Clustered Bootstrapped p-values and t-statistics for table 1.7

Pollutant		(I)	(II)	(III)	(IV)
VOC	t-stat	-2.7678	-3.0220	-0.7142	-0.7537
	p-value	0.0114	0.0012	0.7157	0.7157
PM10	t-stat	-4.5540	-2.2413	4.1499	4.3795
	p-value	0.0001	0.0538	0.0000	0.0000
PM	t-stat	-3.7356	-3.4771	-2.4073	-2.5405
	p-value	0.0013	0.0001	0.0001	0.0001
NOX	t-stat	-2.2658	-3.4909	-2.0308	-2.1432
	p-value	0.0397	0.0001	0.0001	0.0001
NO	t-stat	-2.2664	-3.4783	-1.9817	-2.0913
	p-value	0.0394	0.0001	0.0001	0.0001
NMVOC	t-stat	-2.5582	-3.0507	-1.0176	-1.0739
	p-value	0.0203	0.0011	0.3246	0.3246
CO	t-stat	-3.3575	-2.0350	3.2572	3.4374
	p-value	0.0017	0.0524	0.0012	0.0012
PM25	t-stat	-4.4913	-2.3343	3.8384	4.0508
	p-value	0.0001	0.0395	0.0001	0.0001

on human health is more harmful. These categories can be seen in table A.6. Table A.7 shows the different levels of the pollutant associated with selected values of the API.

Table A.6: API Classification

API	*Air Quality Condition*
0-50	Optimal
51-100	Good
101-150	Slight Pollution
151-200	Light Pollution
201-250	Moderate Pollution
251-300	Moderate Heavy Pollution
>300	Heavy Pollution

Table A.7: Calculation Interval of API Classification

API	Pollutant Concentration (mg/m3)				
	SO2	NO	PM10	CO	O3
50	0.05	0.08	0.05	5	0.12
100	0.15	0.12	0.15	10	0.2
200	0.8	0.28	0.35	60	0.4
300	1.6	0.565	0.42	90	0.8
400	2.1	0.75	0.5	120	1
500	2.62	0.94	0.6	150	1.2

A.4 Using Emissions of Engine Size Less than 2 liters as Control.

Table A.8: Effect on the Total emissions Different Engine Trends (2 Litters as Control)

Pollutant	*(I)*	*(II)*	*(III)*	*(IV)*
VOC	-0.1078	-0.0870	-0.0026	-0.0026
	0.0363	0.0300	0.0106	0.0101
PM10	-0.0117	-0.0050	0.0039	0.0039
	0.0023	0.0022	0.0009	0.0008
PM	-0.0010	-0.0007	-0.0001	-0.0001
	0.0002	0.0002	0.0001	0.0001
NOX	-0.0670	-0.0594	-0.0112	-0.0112
	0.0208	0.0168	0.0067	0.0063
NO	-0.0643	-0.0568	-0.0103	-0.0103
	0.0200	0.0161	0.0064	0.0061
NMVOC	-0.0912	-0.0792	-0.0057	-0.0057
	0.0335	0.0272	0.0098	0.0093
CO	-1.0904	-0.5516	0.3886	0.3886
	0.3241	0.2939	0.1067	0.1011
PM25	-0.0067	-0.0030	0.0020	0.0020
	0.0013	0.0013	0.0005	0.0004
Trend by Engine	*Yes*	*Yes*	*Yes*	*Yes*
Time Control	*No*	*No*	*yes*	*Yes*
Province Control	*No*	*Yes*	*Yes*	*No*
Observations	*304*	*304*	304	*304*

Note: Clustered standard errors by province are in parenthesis. Each row is the estimate of γ_3, and every column corresponds to a different regression estimate that includes a specific linear trend by engine size or a full set of year controls or a full set of province dummies. All the regressions include economic condition variables like GDP per capita and unemployment rates.

Table A.9: Effect on the Total emissions Different Engine Trends No Beijing (2 Litters as Control)

Pollutant	*(I)*	*(II)*	*(III)*	*(IV)*
VOC	-0.1093	-0.0870	-0.0026	-0.0026
	0.0367	0.0300	0.0102	0.0097
PM10	-0.0105	-0.0050	0.0038	0.0038
	0.0022	0.0022	0.0009	0.0008
PM	-0.0009	-0.0007	-0.0001	-0.0001
	0.0002	0.0002	0.0001	0.0001
NOX	-0.0567	-0.0594	-0.0108	-0.0108
	0.0216	0.0168	0.0066	0.0062
NO	-0.0544	-0.0568	-0.0100	-0.0100
	0.0207	0.0161	0.0063	0.0060
NMVOC	-0.0943	-0.0792	-0.0055	-0.0055
	0.0340	0.0272	0.0094	0.0089
CO	-1.1258	-0.5516	0.3666	0.3666
	0.3237	0.2939	0.1030	0.0976
PM25	-0.0060	-0.0030	0.0020	0.0020
	0.0013	0.0013	0.0005	0.0004
Trend by Engine	*Yes*	*Yes*	*Yes*	*Yes*
Time Control	*No*	*No*	*yes*	*Yes*
Province Control	*No*	*Yes*	*Yes*	*No*
Observations	*294*	*294*	294	*294*

Note: Clustered standard errors by province are in parenthesis. Each row is the estimate of γ_3, and every column corresponds to a different regression estimate that includes a specific linear trend by engine size or a full set of year controls or a full set of province dummies. All the regressions include economic condition variables like GDP per capita and unemployment rates.

Appendix B

Appendix for Chapter 2

B.1 Skill Index

I use Confirmatory Factor Analysis (CFA) to create our skills index using the information about abilities required for jobs in the O*NET. I weight each index using the Labor Force Survey (LFS) so that it can be interpreted as standard deviations of distributions of skill in the labor force in Canada. This exercise is equivalent to **?**.

The O*NET data contains very detailed information about skills required for each job; many of these are correlated and represents one underlying skill. Therefore, CFA is a very suitable technique to reduce the dimension of the information and recover everything in one single index. I then generate 3 skills measure: Social, Cognitive and Strength.

To match the codification of the occupations in the LFS 2015, which use the Canadian Standard Occupation Classification, and the codification in the O*NET database, I use the crosswalks posted in the O*NET webpage. In some cases, two occupations in the O*NET-SOC codification were matched into one in the Canadian. For these cases, I use two approaches: The first one was to randomly match one of the repeated values in the O*NET-SOC into the Canadian one. The second was averaging the value of the information of those repeated values required for each job and matching it with the Canadian pair. The results presented in the paper do not change conditional on how I matched the information.

B.1.1 Social Skill Index

I construct an index that recover Interpersonal skills using ten variables, the first six are listed in the Abilities section in the O*NET database and the remaining four in the job incumbent rating. Table B.1 shows the variables and B.2 the PC loadings:

B.1.2 Cognitive Skill Index

I construct an index that recover Cognitive skills using eight variables. The first six are listed in the Abilities section in the O*NET database and the remaining two in the job incumbent rating. Table B.3 shows the variables and B.4 the PC loading:

B.1.3 Strength Skill Index

I construct an index that recovers Strength skills using six variables, the first four are listed in the Abilities section in the O*NET database and the remaining two in the job incumbent rating. Table B.3 shows the variables and B.4 the PC loading:

B.2 Changes in Childcare and Welfare Policy in Canada during 1990s

In 1966, the federal government introduced the Canada Assistance Plan in order to attempt to consolidate the various independent pieces of legislation passed by provinces for their general welfare assistance programs. It was based on three important conditions that each province had to meet: welfare programs must issue assistance based on need; provinces must no impose residency requirements, and each province must implement an appeal procedure. The constitution act specified in 1982 that each province was to be responsible for designing, managing, and delivering its own social assistance package. It also stipulated that the federal government equally with the provinces would share the cost of social assistance (Sabatini and Nightingale, 1999).

In the 1970s, social spending began to increase because of the expansion of the range

Table B.1: Variables Used to Construct the Social skill index

Variable ID	***Variable Name***	***O*NET Description***
1A1a1	Oral Comprehension	The ability to listen to and understand information and ideas presented through spoken words and sentences.
1A1a2	Written Comprehension	The ability to read and understand information and ideas presented in writing.
1A1a3	Oral Expression	The ability to communicate information and ideas in speaking so others will understand
1A1a4	Written Expression	The ability to communicate information and ideas in writing so others will understand.
1A4b4	Speech Recognition	The ability to identify and understand the speech of another person.
1A4b5	Speech Clarity	The ability to speak clearly, so others can understand you.
4A4a1	Interpreting the Meaning of Information for Others	Translating or explaining what information means and how it can be used.
4A4a2	Communicating with Supervisors, Peers, or Subordinates	Providing information to supervisors, coworkers, and subordinates by telephone, in written form, e-mail, or in person.
4A4a3	Communicating with Persons Outside	Communicating with people outside the organization, presenting the organization to customers, the public, government, and other external sources. This information can be exchanged in person, in writing, or by telephone or e-mail.
4A4a4	Establishing and Maintaining Interpersonal Relationships	Developing constructive and cooperative working relationships with others, and maintaining them over time.

Table B.2: PC loading for the Social skill index

Variable ID	***Factor Loading***
1A1a1	0.9267
1A1a2	0.926
1A1a3	0.9435
1A1a4	0.9269
1A4b4	0.8444
1A4b5	0.8667
4A4a1	0.7792
4A4a2	0.836
4A4a3	0.8392
4A4a4	0.8197
Eigenvalue	7.6116
% of Variance	0.7612

and number of social programs between 1966 and 1973. Increased funding made it possible to improve income security, particularly for the elderly as a result of the Old Age Security and the Guaranteed Income Supplement, for persons with disabilities, for single parents, and for the unemployed. However, in the 1970s and early 1980s, rising inflation and the growing demands of newly unionized public sector employees increased demands on public expenditures as well. These conditions ushered in a new conservative political approach ((Moscovitch, 2019)).

Between 1984 and 1993, the federal government introduced a range of measures to reduce expenditures on social programs including gradually reducing old-age security benefits; eliminating family allowances; reducing the range of workers covered by and the benefits available under unemployment insurance; and limiting cost-sharing under the Canada Assistance Plan in 1990. The decades of 1990s experienced a significant amount of changes for the Welfare Assistance programs in Canada. By 1995, more than 10% of the Canadian population was receiving any kind of social assistance. This put a substantial pressure in both, federal and provincial budgets leading to necessary changes in social welfare programs.

In 1994, a discussion paper called "Improving Social Security in Canada" was released. It provided recommendations for employment services, unemployment insurance, student loans and the Canada Assistance Plan. The 1995 budget announced the termination of the Canada Assistance Plan in 1996 and significant reductions in federal funding for social assistance,

Table B.3: : Variables Used to Construct the Cognitive skill index

Variable ID	***Variable Name***	***O*NET Description***
1A1b4	Deductive Reasoning	The ability to apply general rules to specific problems to produce answers that make sense.
1A1b5	Inductive Reasoning	The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).
1A1b6	Information Ordering	The ability to arrange things or actions in a certain order or pattern according to a specific rule or set of rules (e.g., patterns of numbers, letters, words, pictures, mathematical operations).
1A1b7	Category Flexibility	The ability to generate or use different sets of rules for combining or grouping things in different ways.
1A1c1	Mathematical Reasoning	The ability to choose the right mathematical methods or formulas to solve a problem.
1A1c2	Number Facility	The ability to add, subtract, multiply, or divide quickly and correctly.
4A2b1	Making Decisions and Solving Problems	Analyzing information and evaluating results to choose the best solution and solve problems.
2C4a	Mathematics	Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.

Table B.4: PC loading for the Cognitive skill index

Variable ID	***Factor Loading***
1A1b4	0.9373
1A1b5	0.9083
1A1b6	0.9192
1A1b7	0.8858
1A1c1	0.9087
1A1c2	0.8635
4A2b1	0.7656
2C4a	0.8105
Eigenvalue	6.1474
% of Variance	0.7684

Table B.5: Variables Used to Construct the Strength skill index

Variable ID	***Variable Name***	***O*NET Description***
1A3a1	Static Strength	The ability to exert maximum muscle force to lift, push, pull, or carry objects.
1A3a3	Dynamic Strength	The ability to exert muscle force repeatedly or continuously over time. This involves muscular endurance and resistance to muscle fatigue.
1A3a4	Trunk Strength	The ability to use your abdominal and lower back muscles to support part of the body repeatedly or continuously over time without "giving out" or fatiguing.
1A3b1	Stamina	The ability to exert yourself physically over long periods of time without getting winded or out of breath.
4A3a1	Performing General Physical Activities	Performing physical activities that require considerable use of your arms and legs and moving your whole body, such as climbing, lifting, balancing, walking, stooping, and handling of materials.
4A3a2	Handling Moving Objects	Using hands and arms in handling, installing, positioning, and moving materials, and manipulating things.

Table B.6: PC loading for the Strength skill index

Variable ID	***Factor Loading***
1A3a1	0.9413
1A3a3	0.9723
1A3a4	0.9371
1A3b1	0.9569
4A3a1	0.9725
4A3a2	0.9339
Eigenvalue	5.4433
% of Variance	0.9072

post-secondary education and health care. In 1996 the Canada Health and Social Transfer (CHST) replaced the Canada Assistance Plan. Between 1994 and 1998 the government cut $6.3 billion in health and social program transfers under the CHST (Moscovitch, 2019). In early 1997, federal-provincial discussions led to an agreement to create a new childcare benefits. The 1997 federal budget proposed the creation of a National Child Benefit system based on combining the Child Tax Benefit and the Working Income Supplement into one program (Moscovitch, 2019). By the end of the 1990s almost every province in Canada also created its own children's support benefit that either complemented or substituted the federal program. Table B.7 provides a summary of all the significant changes at the provincial and federal level for child support.

Not only childcare policies suffered changes in the 1990s, the Canada/Quebec Pension Plan Disability (C/QPPD) program. Individuals who have a prolonged and severe disability that prevents them from working and who satisfy the contribution requirements of the plans can apply for these benefits. The QPPD and CPPD are administered separately, being the former only for Quebec residents, while the former for the rest of Canada. Table B.8, taken from Campolieti and Riddell (2012), shows the main changes to both of these programs in the 1990s.

The provinces of British Columbia and New Brunswick lunched a project named the Self-Sufficiency Project (SSP) designed to provide a rigorous test of a temporary earnings supplement, evaluated using random assignment. The beneficiaries received a generous earrings supplement for those leaving welfare to take full-time employments. The Canadian government during the 1990s funded this program and it was focused on single parents with children. This program has been extensively studied to understand the effects of such programs on work incentives on welfare recipients (see for example, (Riddell and Riddell, 2014)).

Table B.7: Changes in childcare policies in Canada during 1990s

Province	**Program**	**Start**	**Notes**
Federal	The National Child Benefit Supplement (NCBS)	1998	Administered by the Canada Revenue Agency and integrated in one monthly payment with the federal CCTB and NCBS
Newfoundland and Labrador	The Newfoundland Child Benefit	1999	Social Assistance payments were not clawed back, but adjustments for family size in social assistance payments was changed in 1999 when the Newfoundlad Child benefit was introduced
Prince Edward Island	No child Benefit Program	NA	Full reduction of NCBS paytment on provincial social assistance payments
Nova Scotia	The Nova Scotia Child Benefit	1998	Families with 1 to 3 children receive different payments. Initially in 998 the payments ranged from $250 for the first child to $136 to the third. Full reduction of social assistance payments until 2001. After 2001 the social assistance payment structure for family size was adjusted instead
New Brunswick	The New Brunswick Child Tax Benefit	1997	The benefit is $250 per child annualy. No reduction on social assistance payments
Ontario	The Ontario Child Care Supplement for Working Parents	1997	Full reduction of oscial assitance for NCBS payments until July 2004. From 2004, the increments to NCBS were protected from the reduction.
Manitoba	No new benefit specifically part of the NCB	1980	A pre-existing benefit called CRISP was in existence since the 1980s. It required a separate provincial application and oscial assistance recipients were not eligible.
Saskatchewan	The Saskatchewan Child Benefit	1998	No reduction in social assistance payments, but it shrank dollar for dollar with NCBS increases through time.
Alberta	An Employment-related child benefit	1997	Phase-in rate of 8% for earnings over $6,500 up to a maximum of $250 for one child and $500 for two more. The benefit is clawed back at a rate of 4% for incomes over $25,000.
British Columbia	The BC Family Bonus	1996	The NCBS is substracted from the BC Family Bonus, rendering it to zero by 2005 since the NCBS is now larger than the prescribed BC family bonus payments. There is no reduction of social assitance for the NCBS payments.

Table B.8: Changes CPPD and QPPD in Canada during 1990s

Year	CPPD	QPPD
1993	No changes	1. Substantial changes to the medical adjudication process increasing the extent of medical history and testing required for assessment. 2. Less labor force attachment required with contribution requirements lowered to the CPPD level (i.e., 2 of the last 3 years or 5 of last 10 years, see below on CPPD). 3. Language inserted to allow greater flexibility for the Board to use the Regulations to change the medical conditions and circumstances to be considered disabled.
1995	1. Work incentives introduced: Beneficiaries can volunteer or attend schooling without losing benefits; 3 month work trial without losing benefits; fast-track of re-application post 3 month work trial if same disability prevents sustained employment. 2. New medical adjudication guidelines/appeals process; in particular downplaying the use of "socio-economic factors" in assessing disability. 3. Minor client services-related changes relating to appeals and the disclosure of medical information.	No changes.
1997	1. Earnings-related portion of the disability benefit changed to be based on last 5 working years (instead of 3 years), in effect lowered maximum benefit by about $147 per year on average. 2. Greater labor force attachment required for eligibility, an increase in contribution to four of last six years (instead of 2 of last 3 or 5 of last 10). 3. Contribution rates increased substantially as part of a move towards fuller funding. 4. Death benefits changed to be less generous. 5. Vocational rehabilitation program (introduced as pilot in 1993) made permanent.	1. Benefit and contribution rates changed in same way as CPPD (except for the survivors benefit) 2. Three month rule introduced where if the beneficiary worked for three consecutivemonths (at an earnings equivalent to full-time at minimum wage) they would no longer be considered disabled.

Appendix C

Appendix for Chapter 3

C.1 First Order Stochastic Dominance Test

Table C.1: First Order Stochastic Dominance Test (Equality)

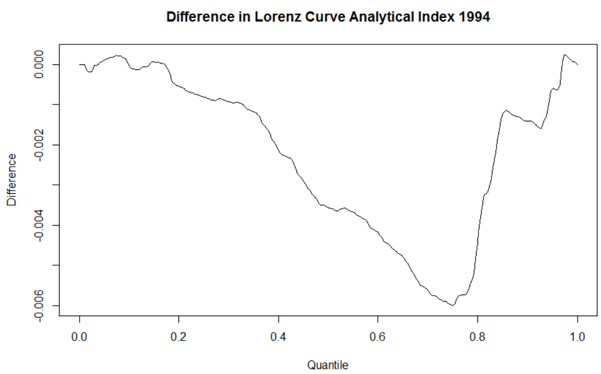
Skill Index	1994		2004	
	CV	KS	CV	KS
Analytical	0.019	0.026	0.041	0.043
	(0.013)	(0.000)	(0.000)	(0.000)
Physical	0.031	0.047	0.059	0.052
	(0.000)	(0.000)	(0.000)	(0.000)
Interpersonal	0.023	0.033	0.034	0.037
	(0.001)	(0.000)	(0.000)	(0.000)
Fine Motor	0.051	0.049	0.060	0.055
	(0.000)	(0.000)	(0.000)	(0.000)
Visual	0.042	0.046	0.053	0.051
	(0.000)	(0.000)	(0.000)	(0.000)

Bootstrap p-value with 1000 repetitions are in parenthesis.

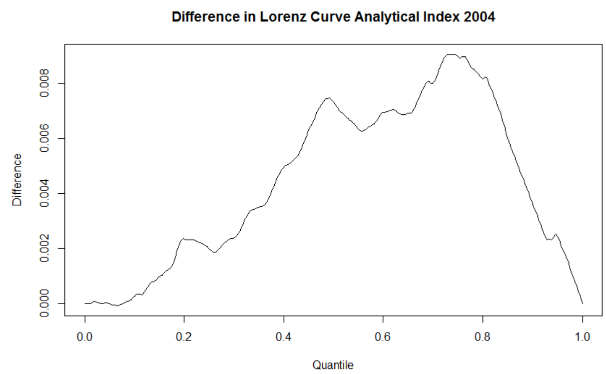
C.2 Differences in Lorenz Curves

Figure C.1: Difference in Lorenz Curves for the Analytical and Interpersonal Skill Index 1994 and 2004

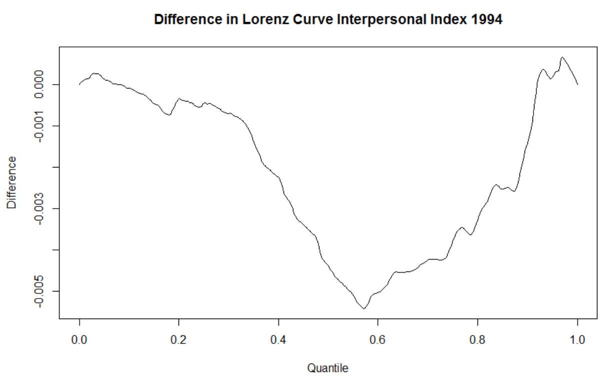
(a) Analytical Motor Index 1994



(b) Analytical Motor Index 2004



(c) Interpersonal Index 1994



(d) Interpersonal Index 2004

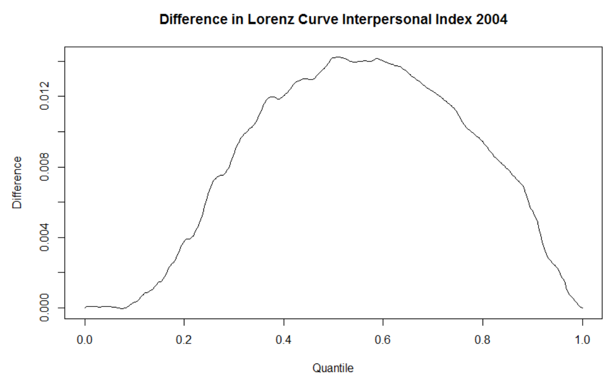
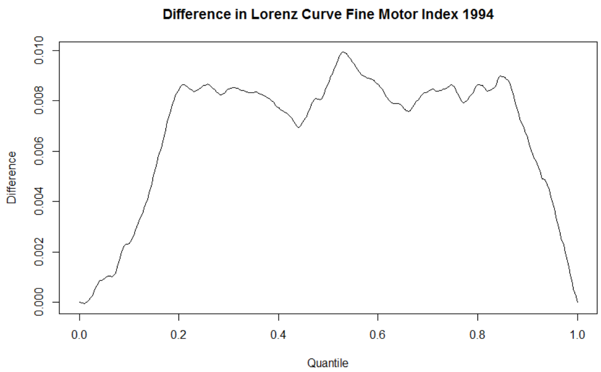
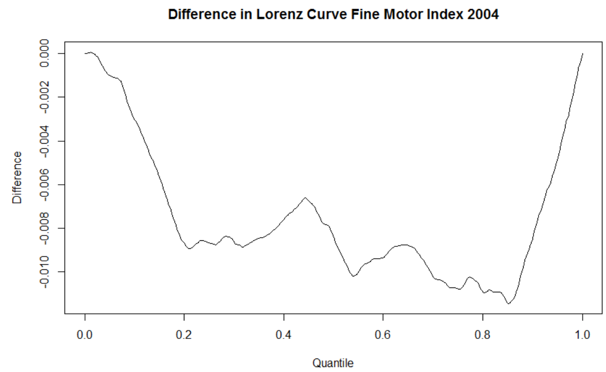


Figure C.2: Difference in Lorenz Curves for the Fine Motor, Visual and Physical Skill Index 1994 and 2004

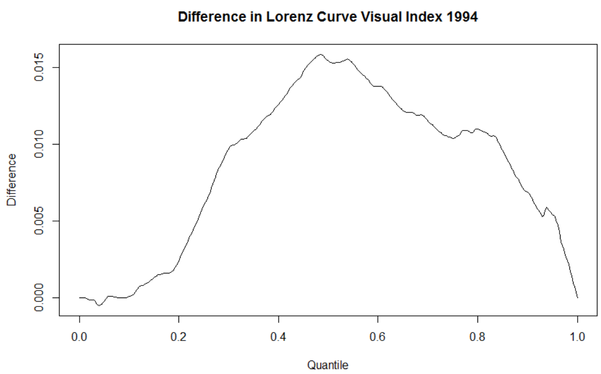
(a) Fine Motor Index 1994



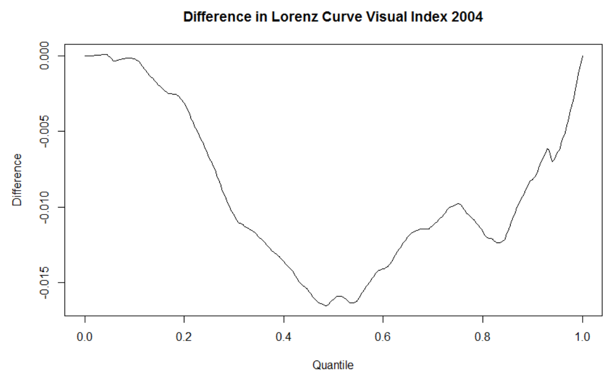
(b) Fine Motor Index 2004



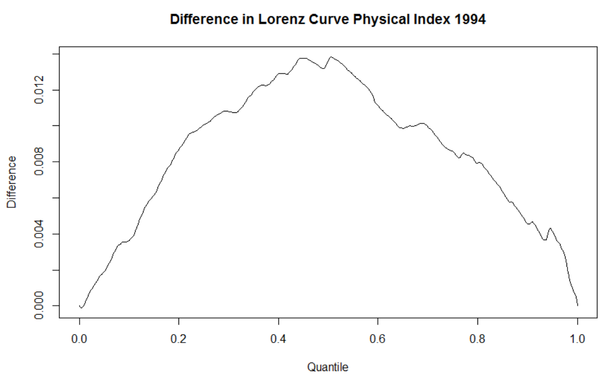
(c) Visual Index 1994



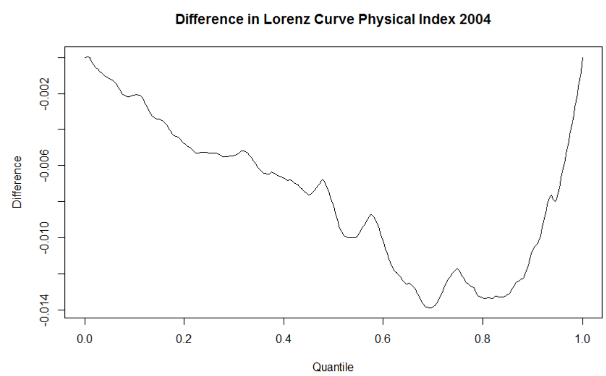
(d) Visual Index 2004



(e) Physical Index 1994



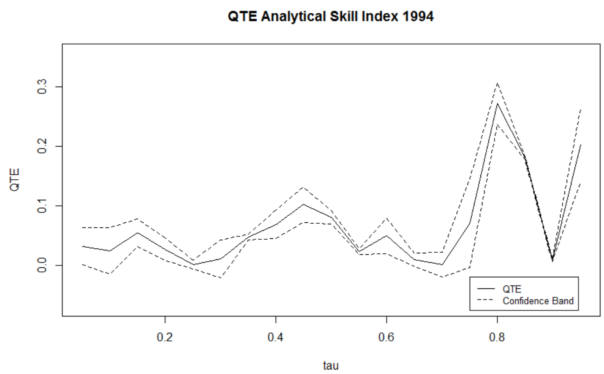
(f) Physical Index 2004



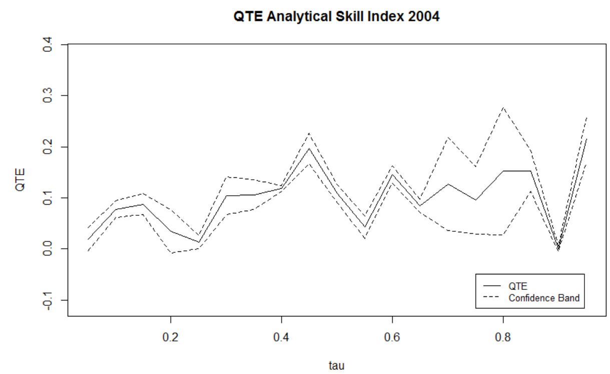
C.3 Quantile Treatment Effects

Figure C.3: Unconditional QTEs I

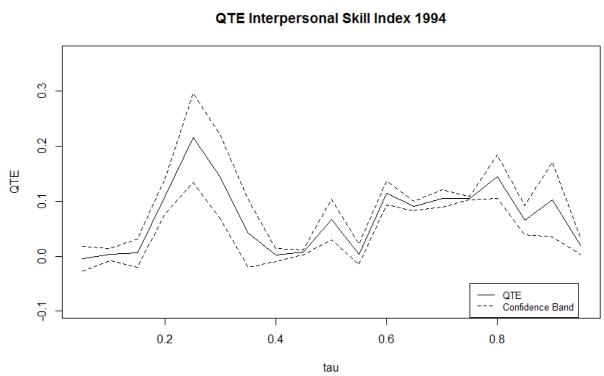
(a) Analytical Index 1994



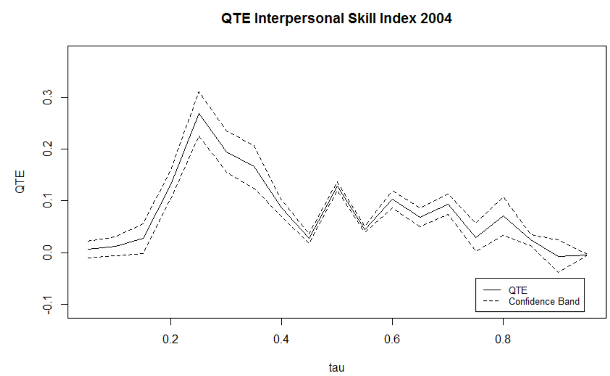
(b) Analytical Index 2004



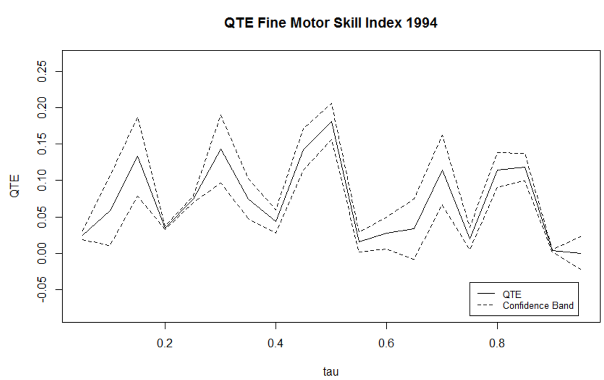
(c) Interpersonal Index 1994



(d) Interpersonal Index 2004



(e) Fine Motor Index 1994



(f) Fine Motor Index 2004

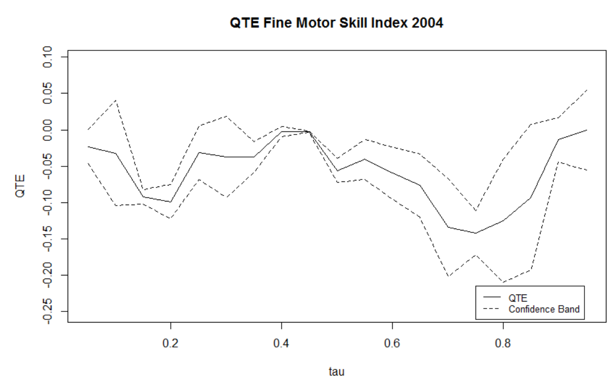
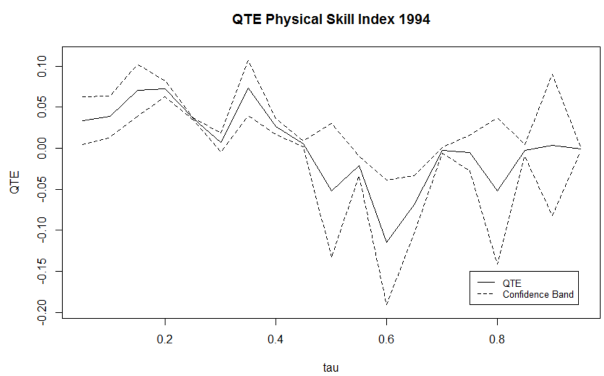
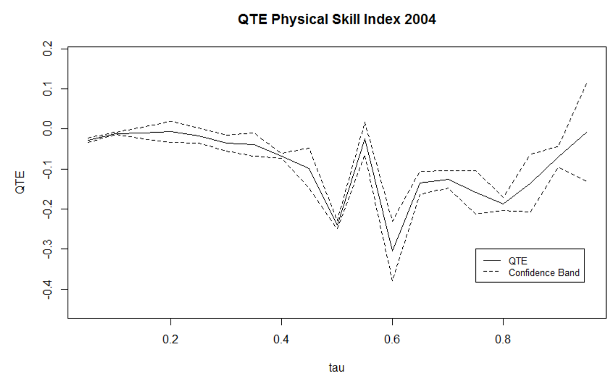


Figure C.4: Unconditional QTEs II

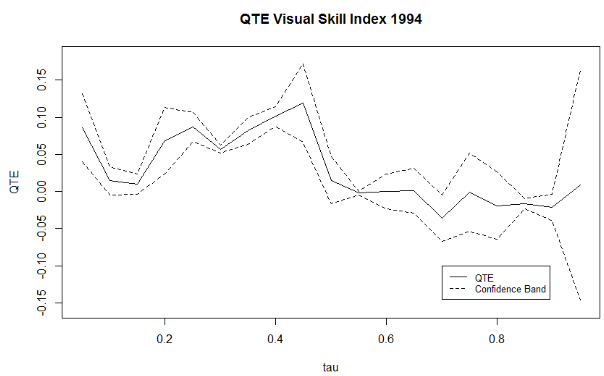
(a) Physical Index 1994



(b) Physical Index 2004



(c) Visual Index 1994



(d) Visual Index 2004

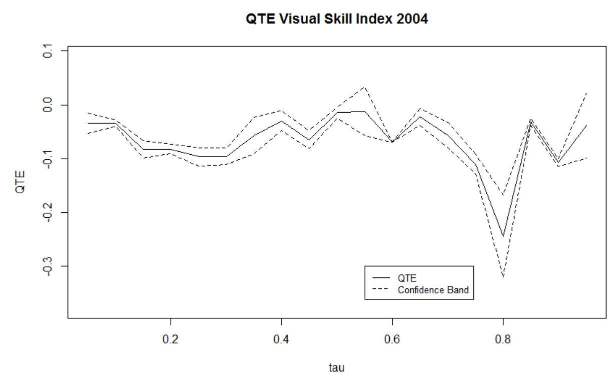
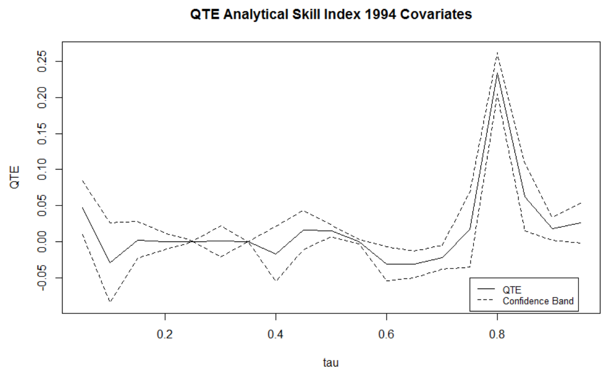
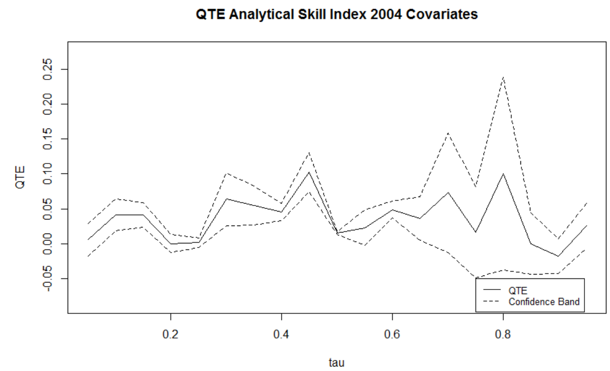


Figure C.5: Conditional QTEs I

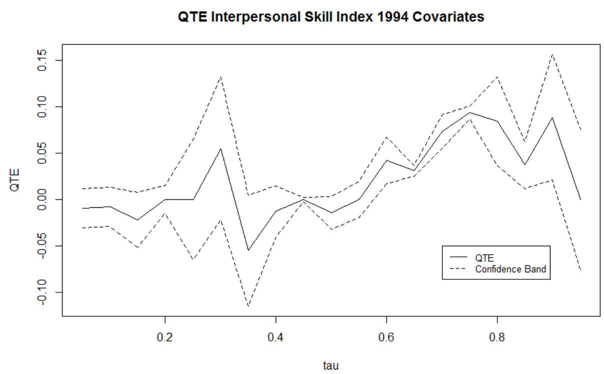
(a) Analytical Index 1994



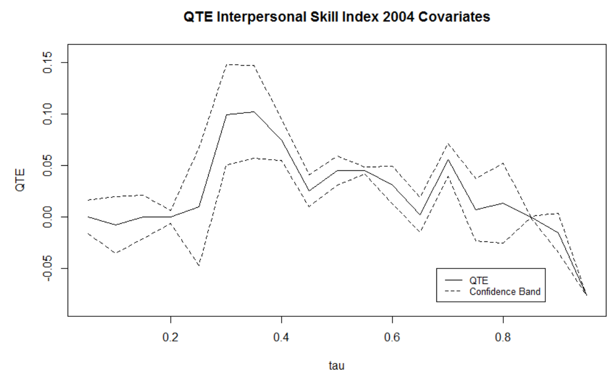
(b) Analytical Index 2004



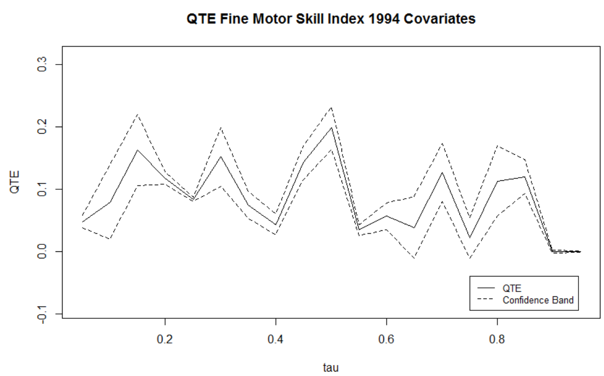
(c) Interpersonal Index 1994



(d) Interpersonal Index 2004



(e) Fine Motor Index 1994



(f) Fine Motor Index 2004

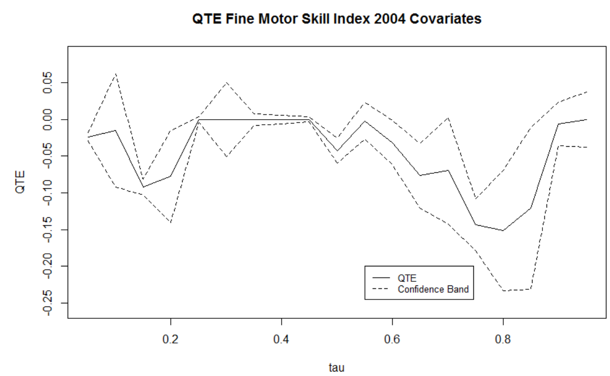
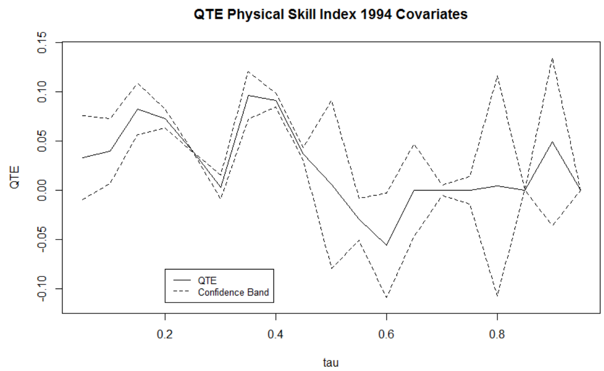
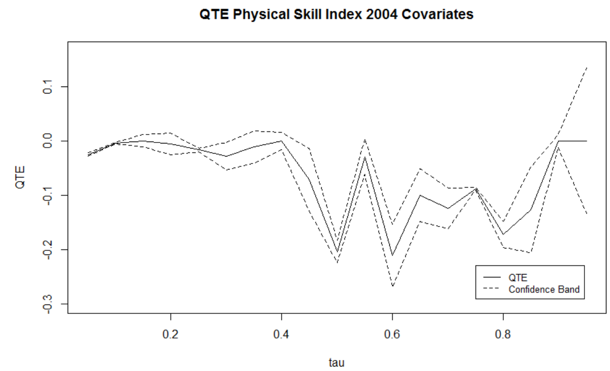


Figure C.6: Conditional QTEs II

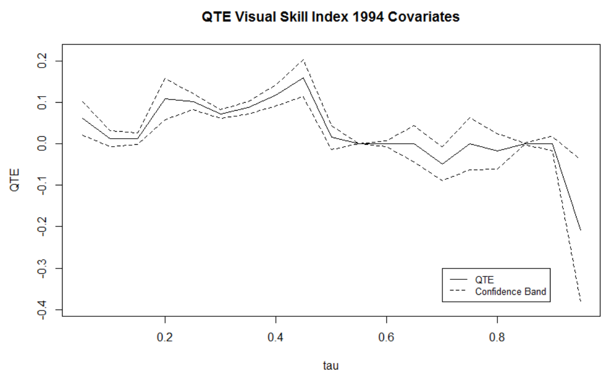
(a) Physical Index 1994



(b) Physical Index 2004



(c) Visual Index 1994



(d) Visual Index 2004