Essays on Delegation and Policy Evaluation

by

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Abstract

In the first chapter of this thesis, my co-author and I study the tradeoff resulting from delegation of authority. Delegating decisions to an agent may benefit the principal if the agent is more informed; however, it shifts the control from the principal to the agent. We show that the principal delegates the authority when the incongruence between her and the agent (manifesting itself through externalities for principal) are not too pronounced. We then examine the effect of change in project payoff distribution on the attractiveness of delegation. We find that for families of distributions which satisfy the Monotone Likelihood Ratio Property, more favorable distributions always move the delegation range such that when externalities are positive, delegation becomes less attractive, and vice versa.

The last two chapters of this thesis evaluate public policies in Canada and Iran. In the second chapter, I study the effects of covering IVF expenses under public health insurance on multiple birth rates in Canada, using a difference-in-difference model. I find little evidence that the coverage of IVF costs under public healthcare led to any significant increase in multiple birth rates. On the contrary, the coverage may have resulted in fewer multiple births, through mechanisms like single embryo transfer mandates, and the lower pressure on the patients to transfer multiple embryos in one cycle to reduce out of pocket costs.

Chapter 3 studies the effectiveness of the Iranian "1993 Population Control Law". My co-author and I use data from publicly available sample 2006 census data in Iran and the annual Household Expenditure and Income Surveys (HEIS: 1988-2005) to estimate the effect of this policy on fertility outcomes. Our difference in difference method compares the change in probability of another birth in families with fewer than three children prior to the legislation to that of families with three or more children. We find that the legislation had a modest effect of 8 to 13 percent on decreasing the probability of a fourth or higher birth. The law has the highest impact after four years of implementation and after that its effect gradually vanishes.

Keywords: delegation; program evaluation; population control policy; public health policy; fertility

Dedication

To my partner Mohammad Reza
who is my rock,
& to my loving parents,
Nahid and Kazem.

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Chapter 1

Delegation without Communication

Abstract

An essential agent (he) can undertake a project and has private information about its (positive or negative) payoffs θ. When the project is completed, these payoffs become relevant for both the agent and the principal (she) who in addition, incurs an externality c. After learning c, the principal can decide whether to delegate authority over project completion to the agent, or to retain this authority. We first show that she will always delegate over some non-empty range of externalities $[\dot{c} < 0, \tilde{c} > 0]$ which includes $c = 0$. When the distribution of project payoffs improves, the effect on the attractiveness of delegation is generally ambiguous. However, we find that for families of distributions which satisfy the Monotone Likelihood Ratio Property (MLRP), more favorable distributions always move the delegation range 'to the left': when externalities are positive, delegation becomes less attractive, and vice versa. We also show that if the parties share the project payoffs, the principal may strictly benefit from allowing the agent a larger payoff share.[1]

Keywords: delegation; program evaluation; population control policy; public health policy; fertility

[1]This paper is co-authored by Professor Christoph Lülfesmann and I.

1.1 Introduction

Consider a technology firm that must make frequent decisions about their products, the technology that should be used and the methods to be employed. In smaller firms, these decisions may be made by founders/owners of the firm and communicated to the rest of the organization for implementation. However, this strategy will make larger tech firms or tech giants with multiple simultaneous projects sluggish and unable to compete in today's fast-paced innovation environment where even short delays in product launch may result in loss of substantial market share. In such cases it may be more beneficial for the leadership to provide the vision and direction for the firm, and/or its different sections, and to delegate making technical decisions to different teams within the organization as they work towards that vision.

In this paper, we formulate this problem with a simple authority delegation model within the Principal-Agent framework. In particular, we examine whether, and under what circumstances, the leadership of the company (the principal) will delegate authority to a particular project team leader (the agent). The assumption here is the presence of information asymmetry. It seems natural for the project team leader to possess more accurate information about a project's true payoff prior to its implementation. This payoff θ is the agent's private information, although it is relevant for both the company management and the project team. We also assume that the project creates an externality of size c for the whole company. For example, the project may generate profitable synergies across the firm (positive externality); conversely, it may conflict with the activities of other divisions, or create compatibility issues (negative externalities). The principal oversees these externalities and in knowledge of c, chooses whether or not to delegate authority over the project to the agent. If she does, the agent decides whether to pursue the project, and she will do so whenever the project has positive payoffs. Alternatively, a principal who retains authority will have to base her project decision only on her anticipation of expected project returns, as well as the knowledge of externalities involved. These considerations reveal a basic tradeoff in the principal's decision making: decisions under agent authority disregard externalities (even if those are known to the agent), whereas decisions under principal authority suffer from the principal's lack of information regarding the realization of project payoffs.

Models of authority (and its delegation) are vastly studied in the literature. While this literature also focuses on the tradeoff between preference misalignment of the principal and the agent vs. the superior information of the agent, the setting usually differs from the framework studied in this paper. In the standard model, pioneered by Crawford and Sobel (1982), the parties choose among various projects that can be ordered on the real line. The agent has private information about a state which defines the identity of the payoff maximizing project, and pursuing a sub-par project involves losses (usually a 'quadratic loss' function) which are increasing in the distance to the payoff maximizing choice. The distance between the optimal projects of the principal and the agent represents the agent's 'preference bias', and is usually considered as constant across states. Hence, the principal's choice whether to delegate trades off the agent's preference bias (the 'externality' in our model), for the latter party's superior information.[2] If projects themselves are contractible, the principal may benefit from restricting the agent's choice set to only a subset of possible projects. The standard model addresses two important questions. First, how does the attractiveness of delegation interact with the size of the agent's preference bias? And second, what is the optimal decision rule in case of delegation?

Our binary-choice model replicates the first central result of the delegation literature: when externalities are sufficiently small, the principal always prefers the delegation of authority. This result is immediately intuitive when one remembers that in absence of externalities, the preferences of principal and agent are fully aligned. In our model, the agent undertakes the project only when its payoffs turn out to be positive, which is also the decision rule preferred by his principal in the absence of externalities.

However, in contrast to the standard model in the literature where the sign of externalities is irrelevant, we show that the 'delegation range' of externalities is not necessarily symmetric around zero in our binary-choice setting. Hence, not only the size, but also the sign of externalities has a crucial impact on the desirability of delegation. To understand this result, notice that if the principal retains authority, for given project payoff expectation, she will undertake the project only when externalities exceed some lower threshold, say c^*. Otherwise, she prefers not to complete the project and to reap her reservation payoff of zero. Hence, the comparison of principal and agent authority is based on two different scenarios for these two ranges of externalities. Specifically, we show that while the (positive) upper bound of the delegation range always exceeds c^*, so that the principal 'at the margin' completes the project under principal authority, the opposite is true for the (negative) lower bound of the delegation range, which is always smaller than c^*. Comparing these upper and lower bounds, we find that positive externalities are associated with a 'wider' delegation range than negative externalities, whenever the expected payoff realization among negative outcomes $\theta < 0$, exceeds (in absolute terms) the expected payoff realization among positive outcomes $\theta > 0$. This is the case, for example, when there is a relatively high likelihood of 'very negative' project returns relative to 'moderately negative' ones, while positive outcomes are more evenly distributed. For projects which are risky in this sense, the principal will want to delegate across a substantial range of positive externalities, while she delegates across a narrower range when externalities are negative.

[2] In some models, like Crawford and Sobel (1982), the agent can relay information to the principal via cheap talk when the principal does not delegate. In equilibrium, the sender's revealed information is 'coarse' in the sense that it does not fully reveal the agent's private information.

Because of its binary nature, our setting is not suited for an analysis of 'restricted' delegation which is an important feature of the standard model. In exchange, our model admits for variations in the distribution of project payoffs, another important dimension of analysis. This extra dimension allows us to ask how the relative benefits of delegation react to changes in the payoff distribution. Of special interest here is whether the principal finds delegation more or less attractive (for given size of the externalities), when expected project payoffs rise or fall. This analysis is non-trivial as, in general, a switch towards a more favorable distribution, benefits the principal in either regime: under principal authority (and assuming the principal wishes to undertake the project), any change in expected payoffs triggers an identical increase in her utility. Conversely, under the agent authority, the principal benefits from two effects: first, positive project payoffs may improve further; and in addition, a higher likelihood of positive payoffs raises the likelihood of project completion and as such, the principal's prospect of gaining externalities.

Notwithstanding this general ambiguity, we achieve clearcut results for distribution functions which satisfy the monotone likelihood ratio property (MLRP). For this important class of distributions which include the families of normal, exponential, Poisson, and binomial distributions, we show that the delegation range unambiguously 'moves to the left' when the payoff distribution improves. Hence, delegation becomes less likely when externalities are positive, while the negative lower boundary of the delegation range becomes even smaller, so that delegation occurs more often for negative externalities. For our example of a tech firm in a fast moving environment, these results yield a number of interesting – and empirically testable – economic implications: for example, they suggest that when the economic outlook of a business division with positive externalities brightens, the upper management may find delegation less attractive, and it may want to revert towards a more centralized corporate structure.[3]

Lastly, we show that if principal and agent share the project payoffs according to some balanced sharing rule, the principal may strictly benefit from allowing the agent a larger payoff share. In fact, this is the case when expected project payoffs are negative and externalities are positive. In such a situation, increasing the agent's payoff share while retaining principal authority, acts as an insurance device against negative payoff shocks for the principal, while at the same time allowing her to reap the externalities that the project generates for the company as a whole.

As already said, our paper is part of the literature on delegation pioneered by Holmstrom (1978, 1980). Since the different alternative 'projects' in his model are contractible (but contingent transfers are considered infeasible), the principal delegates when the agent's preference bias is not too pronounced, and she often restricts the agent's choice to an

[3]Conversely, the delegation range expands in this case, if project externalities for the parent company are negative.

interval of projects. Alonso and Matouschek (2008) and Kolotilin et al. (2013) build on this work and develop the optimal interval delegation rules in different settings.

Another strand of this literature studies optimal delegation with non-contractible projects. In Dessein (2002), the agent simply implements his most preferred project after delegation, whereas under principal authority, he voluntarily communicates the state via cheap talk. As is common in cheap talk models, information transmission is imperfect, unless the preferences of both parties are fully aligned. Dessein (2002) shows that even though the principal gains some information when she retains authority, delegation (without further communication) is optimal if (and only if) the preferences of both parties are sufficiently aligned. He shows that retention of authority by the principal may not be optimal, since the incomplete nature of the contract allows the agent to strategically select what information they convey to the principal before the latter makes a decision about the project, and hence influence the principal's decision in a Crawford and Sobel (1982) setting.

Aghion and Tirole (1997), among others, examine how the authority structure affects the incentives to acquire payoff-relevant information. They establish that delegating the contractual right of project choice (formal authority) to the agent, makes him devote more effort into the search for profitable projects, at the cost of shifting control over project choice. In case of sufficient congruency between principal and agent preferences, giving up formal authority may be desirable for the principal. In other words, the principal may forgo her decision-making right in exchange for better information. Szalay (2005) sets up an advice model where an agent in a principal-agent setting gathers information before choosing a project. He finds that it may be optimal for the principal to limit the choices of the agent to the 'extreme' options. This may increase the agent's incentives for information gathering to avoid very adverse outcomes.

We present a general formulation of the delegation model in Section 1.2. Section 1.3 investigates the conditions under which the principal decides to delegate the decision over the project to the agent. We discuss how changes in payoff distribution affect the decision to delegate the project to the agent in Section 1.4. Section 1.5 discusses payoff sharing, and Section 1.6 contains some concluding remarks.

1.2 The Model

Consider a firm with different parallel projects delegated to different teams. In this section, we model the decision of the firm owner/manager (hereafter the principal/she/P) to delegate a project to a project team leader (hereafter the agent/he/A). The project returns θ are stochastic where $\theta \in [\underline{\theta}, \bar{\theta}]$ being distributed according the continuous distribution function $F(\theta)$. Suppose both parties are risk neutral. Let the realization of θ be the agent's private information, and assume that the agent cares only about the project payoff. Therefore, his utility is can be written as

$$U^A = x\theta. \tag{1.1}$$

where $x \in \{1, 0\}$ indicates whether or not the project is being undertaken. The completion of the project also creates an externality of size c for the whole firm, and so affects principal's payoff. For $c > 0$ those externalities are positive, so that principal accrues additional benefits from project completion and therefore, may be more inclined to undertake the project than her agent. The opposite is true when $c < 0$ where externalities are negative. We can also introduce a parameter $\beta > 0$ that measures the principal's payoff intensity. With a larger β, project payoffs θ take on larger importance, relative to externalities c. The principal's payoff is therefore modelled as

$$U^P = x[\beta\theta + c], \tag{1.2}$$

where $\beta > 0$ and c are known to the principal (in our setting it does not matter whether or not A knows the realization of β, c).[4,5] To simplify the exposition, we will assume that $\beta = 1$ throughout the main part of our analysis.[6]

Suppose that the principal can either retain authority over project implementation, or delegate this decision to the agent. Moreover suppose, as is often the case in reality, that no additional communication between the two parties takes place.

Notice that project realization benefits the agent whenever $\theta \geq \theta^A \equiv 0$, where θ^A is the agent's reservation payoff. Defining $x_i; i \in \{P, A\}$ as party i's decision about the project, should they have the authority, agent's decision rule is

$$x_A = 1 \quad \text{if} \quad \theta \geq 0, \quad \text{and} \quad x_A = 0 \quad \text{otherwise.} \tag{1.3}$$

In contrast, the principal ideally wishes to implement the project whenever $\theta + c \geq 0$. Hence, her utility maximizing solution would be to complete the project whenever $\theta \geq -c$, which means that the interests of the two parties about the project are misaligned unless $c = 0$. In a scenario where P has full information regarding the project payoff θ, she would therefore

[4] Later on, we will consider the case where P and A share the project payoff θ, which will require a slight modification of these utility functions.

[5] For other examples of where a setting like this may be relevant, consider a fast food chain licensee who renovates his restaurant. This project has a positive externality on brand perception and therefore, on headquarters' utility. Contrarily, cost cutting measures such as reduced cleaning may have a negative impact on the brand. In the political realm, emission control measures adopted in one jurisdiction, not only may directly benefit neighboring jurisdictions (or countries), but also may make it politically easier for governments to introduce likewise measures in those other jurisdictions. This latter effect is an additional positive externality for the government.

[6] All qualitative findings extend to any situation where $\beta > 0$. For $\beta = 0$, P cares only about the externality.

retain authority and apply the full-information decision rule $x_P^* = 1$ if $c \geq -\theta$, and $x_P^* = 0$ otherwise.

Next, consider the principal's decision under P-authority when θ is the agent's private information. Since P knows c but only the distribution of payoffs θ, and can guarantee herself a payoff of zero by not implementing the project ($x_P = 0$), she will choose

$$x_P = 1 \quad \text{iff} \quad U^P(x_P = 1) = \int_{\underline{\theta}}^{\bar{\theta}} [\theta + c] dF(\theta) \geq 0. \tag{1.4}$$

This is the case whenever

$$c \geq c^* \equiv -\int_{\underline{\theta}}^{\bar{\theta}} \theta dF(\theta). \tag{1.5}$$

Defining $\theta^E \equiv \int_\theta \theta dF(\theta)$ as the expected project payoff across the entire range of payoff states, the principal's optimal decision rule means that she implements the project whenever her payoff externality c exceeds $-\theta^E$. Notice that c^* is positive whenever $\theta^E < 0$, and c^* is negative otherwise. While the agent bases his project decision exclusively on the realized state θ, the uninformed principal weighs her payoff externalities against the project's expected payoff. While for given c, A always undertakes the project with positive but less than certain probability, P's choice is always deterministic in the sense that depending on the observed c, she will undertake – or not undertake – the project in all payoff states.

In the next Section, we will analyze whether and under which circumstances, P will decide to delegate authority to the agent.

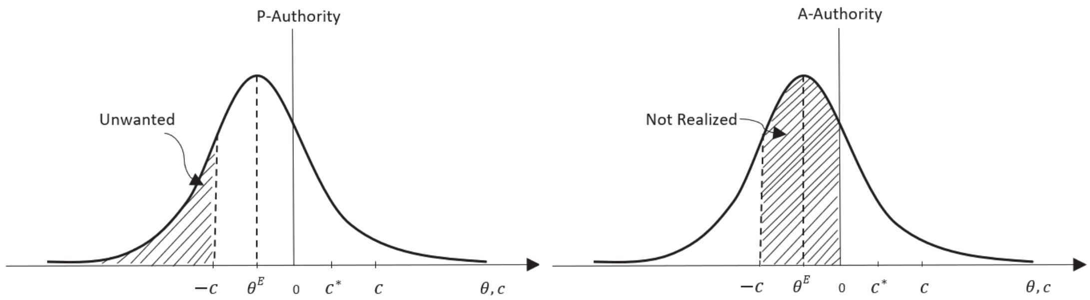
1.3 Decision to Delegate

The principal will delegate whenever conferring authority on the agent enhances her own utility expectation, and she will retain authority otherwise. On the other hand, the agent strictly prefers own authority over operating under the principal's command: his payoffs under the two regimes are identical when θ is positive and $c > c^*$, or whenever θ is negative and $c < c^*$. Agent's payoff is strictly bigger under A-authority in all the other cases.[7]

In order to examine the principal's choice, we therefore need to compare P's expected utility in case that she does, or does not, delegate the decision over her project to the agent. In what follows, U_j^i denotes expected utility of party i if j has the authority over the decision ($i, j \in \{P, A\}$). A crucial determinant of whether P decides to delegate the authority to A is whether P chooses to undertake the project if she retains authority. Having established that $x_P = 1$ whenever $c \geq c^*$, and $x_P = 0$ otherwise, P's expected utility under

[7] A is willing to operate under P authority, and to implement the project even if $\theta < 0$, when his relationship with the principal encompasses a broader range of (lucrative) projects, or, if P pays the agent a sufficiently high salary as to satisfy his ex-ante and ex-post participation constraints.

Figure 1.1: Probability of losses incurred by principal due to imperfect information



The two panels in this figure are drawn for a case where θ is normally distributed, and $c > c^*$, so the principal will green-light the project if she has the authority, but no information on the actual realization of θ. The shaded areas depict the probability of P incurring losses under different authority regimes, compared with the perfect-information outcome.

principal-authority is then given by

$$\begin{aligned} U_P^P(x_P = 0) &= 0, \quad \text{and} \\ U_P^P(x_P = 1) &= c + \theta^E \end{aligned} \tag{1.6}$$

Conversely, under agent authority:

$$\begin{aligned} U_A^P &= \int_{\theta > 0} (\theta + c) dF(\theta) \\ &= (1 - F(0))c + \theta_+^E, \end{aligned} \tag{1.7}$$

where $\theta_+^E = \int_0^{\bar{\theta}} \theta dF(\theta)$. From P's perspective, each governance structure inflicts losses relative to P's preferred outcome, the one achieved under decision rule x_P^*.

As an illustration for the ensuing tradeoffs, consider a situation where $c > c^*$ so that $x_P = 1$ and the principal undertakes the project when she has authority. Figure 1.1 assumes θ to be drawn from a normal distribution. The shaded areas in both graphs indicate the regions where P incurs losses under P-authority and A-authority, compared to her first-best optimum . Note that the two graphs are drawn for a particular realization of c. Under P-authority, P would be better off if she did not undertake the project whenever $\theta < -c$. Under agent authority, the project is not undertaken for negative payoffs, even when $\theta > -c$. This results in unrealized gains for P, compared to the first-best outcome.

1.3.1 Special Cases

Before moving into a general discussion on the relative merits of principal versus agent authority, it is instructive to briefly look into a number of special cases.

1. Zero externalities, $c = 0$: In this case, the preferences of principal and agent regarding project realization are fully aligned. The agent's superior information makes A-authority strictly preferable because $\underline{\theta} < 0$ implies $U_P^P = \max\{0, \theta^E\}$ while $U_A^P = \theta_+^E$, where $\theta_+^E > \max\{0, \theta^E\}$. Hence, $x_A = x_P^*$ and the agent undertakes the project exactly if both parties gain from it.

2. Large positive externalities: Suppose $c > 0$ and the lower payoff bound $\underline{\theta} < 0$ is sufficiently large that $c > |\underline{\theta}|$. In this case, $x_P = x_P^* = 1$, and $P-$authority allows the principal to achieve her perfect-information outcome. As this is not the case under agent authority, P strictly prefers not to delegate.

3. Large negative externalities: Assume $c < 0$ and the upper payoff bound $\bar{\theta} > 0$ is so small that $|c| > \bar{\theta}$. In this case, $x_P = x_P^* = 0$ and P achieves the perfect-information outcome. Agent authority is dominated as in every state θ, as the best outcome for the principal is to leave the project alone.

4. Non-negative or non-positive payoffs: Suppose project payoffs are never negative, $\underline{\theta} \geq 0$; or they are never positive, $\bar{\theta} \leq 0$. Under agent authority, $x_A = 1$ ($x_A = 0$) in the former (latter) scenario regardless of θ. Conversely, under principal authority, P chooses $x_P = 1$ whenever $c \geq c^*$. Outcomes in neither authority regime are payoff-optimal for the principal. If project payoffs are never negative, under A-authority, A undertakes the project too often when c is negative. On the other hand, as $\theta^E > 0$, the principal realizes the project too often (when $c > c^*$) or not often enough (when $c < c^*$) compared to the perfect-information case, when she retains authority.

From these special cases, we observe that P will always delegate and achieve a payoff-optimal outcome, when externalities are absent. If this is the case, delegating authority allows P to avoid negative payoffs that she would incur in some states, if she herself went ahead with the project. Likewise, the principal gains positive payoffs in some states in situations where her own decision would have been not to implement the project. We also see that when the principal does not require the agent's superior information to come up with the best project choice (the project will produce positive or negative payoffs for the principal, regardless of the state), P will always retain authority. Finally, we found the relative merits of delegation to be ambiguous in deceptively simple scenarios, where project payoffs are either always positive, or always negative. We are now prepared for a general analysis.

1.3.2 General Case

Suppose first that P delegates authority. Since $x_A = 1$ whenever $\theta \geq 0$, principal's expected payoff is given by Equation (1.7). For future reference, notice that

$$\frac{dU_A^P}{dc} = 1 - F(0). \tag{1.8}$$

The principal's payoff under agent authority, increases in c at a positive rate which is smaller than unity, as the agent undertakes the project only in positive payoff states.

Next, consider P-authority. As denoted by Equation (1.6), the principal's expected payoff in this regime is

$$U_P^P = \max\{\int_{\underline{\theta}}^{\bar{\theta}} (\theta + c) dF(\theta), 0\} = \max\{c + \int_{\underline{\theta}}^{\bar{\theta}} \theta dF(\theta), 0\}. \tag{1.9}$$

The first term in the max-function becomes relevant if P undertakes the project, while she achieves her fall-back utility of zero if she decides to forego it. Hence, our further analysis must distinguish between the two cases.

First, suppose $c \geq c^*$, in which case $x_P = 1$. In this scenario, P retains authority whenever $U_P^P(x_P = 1) \geq U_A^P$. That is, if the externality level c satisfies

$$\int_{\underline{\theta}}^{\bar{\theta}} [\theta + c] dF(\theta) \geq \int_0^{\bar{\theta}} [\theta + c] dF(\theta), \tag{1.10}$$

or

$$c \geq \tilde{c} \equiv -\frac{\theta_-^E}{F(0)} > 0, \tag{1.11}$$

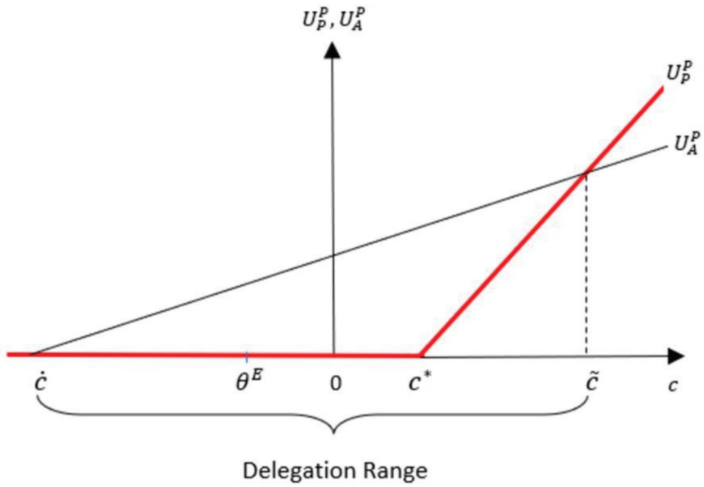
where $\theta_-^E = \int_{\underline{\theta}}^0 \theta dF(\theta)$. The threshold level of externalities $\tilde{c}$, from which on P decides to retain authority, is equal to $\tilde{c} = -\mathbb{E}(\theta \mid \theta < 0)$ and hence, always strictly positive. Next, we show that $\tilde{c}$ exceed c^*. Otherwise, agent authority can never be preferable in situations where $x_P = 1$.

Inspection of Equation (1.10) shows that at $c = c^*$, $U_P^P = 0$ by the definition of c^*, whereas U_A^P is strictly positive at this level of externalities. The agent implements the project only when its payoffs are positive. Moreover, when c^* is positive, externalities further enhance P's payoff. When they are negative, $|c^*| = \theta^E > 0$ so that $(1 - F(0))c^* > -\theta^E$ and $\int_{\theta > 0} \theta dF(\theta) > \theta^E$. Accordingly, $U_A^P > 0$ even in the latter case. Moreover, note that $U_P^P = 0$ for any $c < c^*$ as $x_P = 0$ for any such c, whereas U_A^P globally increases in c at a constant rate of $(1 - F(0)) \in (0, 1)$.

Finally, note that for $c \geq c^*$, Equation (1.9) shows that

$$\frac{dU_P^P}{dc} = 1. \tag{1.12}$$

Figure 1.2: Principal's expected utility under the two authority regimes



The above figure depicts principal's expected utility under the two authority regimes, as a function if c, for a situation where $\theta^E < 0$ so that $c^* > 0$. The slope of $U_P^P = 1$, for $c > c^*$, and the slope of $U_A^P = 1 - F(0)$.

When the principal exerts the project, U_P^P increases at a rate of unity because externalities are always being incurred. Combining this with the previous result (1.8), it necessarily implies that for some threshold level of externalities $c = \tilde{c} > c^*$, $U_P^P(c) = U_A^P(c)$, and $U_P^P(c) > U_A^P(c)$ for any $c > \tilde{c}$.

Next, consider a situation where $c < c^*$, so that $x_P = 0$ and $U_P^P = 0$. In such a case, P prefers retaining authority whenever

$$0 \geq \int_0^{\bar{\theta}} [\theta + c] dF(\theta), \tag{1.13}$$

or

$$c \leq \dot{c} \equiv -\frac{\theta_+^E}{1 - F(0)} (< 0), \tag{1.14}$$

where $\theta_+^E = \int_0^{\bar{\theta}} \theta dF(\theta)$. Notice that $\dot{c} < c^*$, as $1 - F(0) > 0$ and $\int_0^{\bar{\theta}} \theta dF(\theta) > \int_{\theta} \theta dF(\theta)$.

Figure 1.2 (drawn for a situation where $\theta^E < 0$ so that $c^* > 0$) illustrates the above findings.

So far, we have established the following result.

Proposition 1. *There exist unique threshold parameters $\tilde{c}, c^*$, and $\dot{c}$ with $0 > \dot{c} < c^* < \tilde{c} > 0$ such that the principal will delegate authority whenever $c \in (\dot{c}, \tilde{c})$, that is when externalities are sufficiently small in magnitude; conversely, she will retain authority when $c \leq \dot{c}$ and $c \geq \tilde{c}$.*

The principal prefers to delegate authority to A in situations where externalities are not too pronounced. This is true in situations where externalities are positive, as in situations where they are negative. When taking her decision whether to delegate, P weighs the superior information of the agent regarding project returns against her own knowledge of (and her interest in) the level of externalities. As already said, the principal will always delegate in absence of externalities, where preferences of both parties are aligned and the agent takes the payoff-optimal decision for the principal, in every state. When externalities become larger, A authority causes a loss for the principal as the agent does not undertake the project in all the situations where P would like him to, that is to say, for small enough negative project payofss. The opposite is true when externalities are negative and A exerts the project 'too often' from the principal's point of view.

The next section examines how the delegation range depends on the properties of the underlying payoff distribution.

1.4 Changes in the Payoff Distribution

In this section we examine how the threshold levels $\tilde{c}$ and $\dot{c}$ relate to the properties of the project payoff distribution $F(\theta)$. In particular, we would like to examine whether or not delegation becomes optimal across a wider range of externalities, as a response to a shift in the payoff distribution.

This is not a straightforward task. Consider a change in the payoff distribution which increases the expected payoff θ^E, from θ_0^E to a larger value θ_1^E. For any such shift, the principal's expected utility U_P^P when she retains authority and undertakes the project, changes by the same amount as θ^E changes. Notice in particular that the higher moments of the distribution, do not affect this conclusion and the only moment relevant to the question of whether or not P chooses to exert the project is the mean.

In contrast, the higher moments of the distribution play a decisive role when we evaluate changes in P's payoff under A-authority. To illustrate this point, consider that the distribution of θ changes from F_0 to F_1 in such a way that the probability distribution function remains the same for any $\theta \geq 0$. However, expected payoffs increase for $\theta < 0$. While θ^E increases, A will undertake the project in exactly the same circumstances as before. Also, as the payoff expectation for positive realizations $\theta > 0$ does not change, U_A^P remains the same. P-authority therefore gains value over A-authority, and the threshold $\tilde{c}$ falls (whereas $\dot{c}$ does not change). Hence, the delegation range shrinks for positive externalities. Next, consider another simple scenario where the change in θ^E is attributed entirely to changes in likelihood for positive payoffs $\theta > 0$. Notice that now, U_A^A and U_A^P experience identical changes, and the delegation range remains unchanged.

For a more canonical situation, consider a change in the distribution that shifts some weight from negative to positive payoff outcomes θ. In this case, θ^E increases and so does

U_P^P. Any such movement increases the likelihood $1 - F(0)$ with which A undertakes the project when he has discretion, and P benefits (or suffers from) the externality c more often. Moreover, positive payoffs now carry a larger weight, so that U_A^P also benefits from the switch to F_1. However, it is not trivial to see how the relative attractiveness of P-authority versus A authority changes.

As already mentioned, the switch to F_1 increases U_A^P both (for $c > 0$) because of the higher likelihood of project realization, and also from the higher expectation of positive payoffs. While U_P^P benefits in the same way from the latter effect, the former effect is absent as P appropriates c anyway when she realizes the project. In addition, principal authority reduces P's losses from negative θ realizations, and the overall change in U_P^P may or may not outweigh the change in U_A^P. To illustrate this point, let F_1 mostly (but not exclusively) change the likelihoods across negative realizations, $\theta < 0$. Principal (but not agent) authority allows P to take advantage of these changes, whereas the change in the probability $1-F(0)$ that the project is realized under agent authority, will be small. In these circumstances, F_1 makes P authority relatively more attractive and $\tilde{c}$ falls. Conversely, suppose that the likelihoods of 'very' negative realizations remain virtually unchanged, while $(1 - F(0))$ increases in a substantial way, because of marginal changes in likelihood for realizations just below zero. Under these circumstances, θ^E and therefore U_P^P may not change by a lot, whereas the boost in the project rate under agent authority, propels U_A^P. Then, $\tilde{c}$ increases and the delegation range (for positive c) widens.[8]

So far, we have argued that as the regime comparison in response to changes in the payoff distribution, crucially depend on the moments on the distribution, a clear-cut assessment is difficult. As we will demonstrate now, robust conclusions can be gained for various commonly-used types of distribution functions.

1.4.1 Uniform distribution

Consider a family of uniform distributions F_i, shifting supports on the intervals $[\underline{\theta}_i, \bar{\theta}_i]$, with identical widths $\Delta \equiv \bar{\theta}_i - \underline{\theta}_i$. Let F_0 and F_1 be two such distributions with $\theta_1^E > \theta_0^E$. Notice that for each such distribution i, $\theta^E = (1/2)[\bar{\theta}_i - \underline{\theta}_i]$,

$$\theta_+^E = \int_{\theta \geq 0} \theta dF_i(\theta) = (1/2)(1 - F_i(0))\bar{\theta}_i, \tag{1.15}$$

and

$$\theta_-^E = \int_{\theta < 0} \theta dF_i(\theta) = (1/2)F_i(0)\underline{\theta}_i. \tag{1.16}$$

[8]As this example shows, first order stochastic dominance (FOSD) of F_1 over F_0, does not resolve this ambiguity, as FOSD does not impose proper constraints on the moments of the distribution. See our discussion below.

Using these expressions, $\tilde{c}_i$ and $\dot{c}_i$ can easily be computed as

$$\tilde{c}_i = -(1/2)\underline{\theta}_i \qquad \text{and} \quad \dot{c}_i = -(1/2)\bar{\theta}_i. \tag{1.17}$$

For any distribution $j > i$ with $\bar{\theta}_j > \bar{\theta}_i$ (and hence, $\underline{\theta}_j > \underline{\theta}_i$), we therefore have $\tilde{c}_j < \tilde{c}_i$ and $\dot{c}_j < \dot{c}_i$. When the payoff distribution improves from F_i to F_j in the prescribed way, the delegation range shrinks for positive externalities, whereas it expands for negative externalities. The range of externalities for which P delegates retains its width, but the interval moves to the left.[9]

1.4.2 Distributions that satisfy the Monotone Likelihood Ratio Property (MLRP)

Distributions in this class include the normal distribution, the Poisson distribution, the binomial distribution, and the exponential distribution. A distribution F_1 dominates another distribution F_0 according to Monotone Likelihood Ratio Property (MLRP) if for any $\theta_i > \theta_j$,

$$\frac{f_1(\theta_i)}{f_0(\theta_i)} \geq \frac{f_1(\theta_j)}{f_0(\theta_j)}.$$

MLRP implies (but is more demanding than) first order stochastic dominance (FOSD). First order stochastic dominance of F_1 over F_0 requires that $F_1(\theta) < F_0(\theta)$ for any admissible interior θ, with the implication that expected payoffs satisfy $\theta_1^E > \theta_0^E$.[10] Notice that in our model, FOSD implies that $F_1(0) < F_0(0)$ and therefore, $(1 - F_1(0)) > (1 - F_0(0))$.

Moreover, $MLRP$ also implies

$$\int_{\theta>0} \theta dF_1(\theta) > \int_{\theta>0} \theta dF_0(\theta), \tag{1.18}$$

and

$$-\int_{\theta<0} \theta dF_1(\theta) < -\int_{\theta>0} \theta dF_0(\theta). \tag{1.19}$$

Accordingly, the F_1 distribution is characterized by larger (smaller) absolute expected total payoffs, when one focuses only on positive (negative) payoff realizations θ.

We first examine whether and in which way, the threshold $\tilde{c}$ changes as the distribution function improves to F_1. Using the definition of $\tilde{c}$, the threshold falls iff

[9]Consider instead a situation where only $\bar{\theta}$ increases but $\underline{\theta}$ remains the same. In this case, an improvement in the distribution leaves $\tilde{c}$ unaffected whereas $\dot{c}$ falls. Overall, the delegation range expands for negative externalities and remains unchanged when externalities are positive. Opposite results arise if $\underline{\theta}$ increases: Now, $\tilde{c}$ falls but $\dot{\theta}$ is unchanged.

[10]For the normal distribution, the MLRP property generates a family of distributions that are identical except for different modes $\theta_1^m (= \theta_1^E) > \theta_0^m (= \theta_0^E)$.

$$\frac{-\int_{\theta<0}\theta dF_1(\theta)}{F_1(0)} < \frac{-\int_{\theta<0}\theta dF_0(\theta)}{F_0(0)} \quad \text{that is, iff} \quad \frac{F_1(0)}{F_0(0)} > \frac{\int_{\theta<0}\theta dF_1(\theta)}{\int_{\theta<0}\theta dF_0(\theta)}. \tag{1.20}$$

We will now show that this condition is always satisfied under the MLRP. To see this, we first note that because of FOSD, $F_1(0)/F_0(0) = x$ for some $x < 1$. Moreover, MLRP implies

$$\frac{-\int_{\underline{\theta}}^{\hat{\theta}}\theta dF_1(\theta)}{-\int_{\underline{\theta}}^{\hat{\theta}}\theta dF_0(\theta)} \leq x \quad \text{for all} \quad \hat{\theta} < 0 \tag{1.21}$$

and therefore,

$$-\int_{\theta<0}\theta dF_1(\theta) \leq -\int_{\theta<0}\theta x dF_0(\theta) = -x\int_{\theta<0}\theta dF_0(\theta). \tag{1.22}$$

To gain some intuitive understanding, suppose that in comparison to the F_0 distribution, F_1 lowers the probability of *any* outcome $\theta < 0$ to the same ratio $x < 1$. In this case, expected payoffs in these states would be scaled back to the same factor x. However, as under the MLRP the F_1 distribution places relatively more weight on larger payoffs, (absolute) expected payoff under F_1 for $\theta < 0$, will be scaled back by an even larger amount.[11] Combining these properties, we obtain

$$\frac{F_1(0)}{F_0(0)} = x > \frac{-\int_{\theta<0}\theta dF_1(\theta)}{-\int_{\theta<0}\theta dF_0(\theta)}(< x), \tag{1.23}$$

so that condition (1.20) is satisfied and the distributional change to F_1, lowers the threshold $\tilde{c}$.

Using a similar chain of arguments, we can also show that a move from F_0 to F_1 unambiguously lowers $\dot{c}$. Using the definition of $\dot{c}$, this in fact requires

$$\frac{-\int_{\theta>0}\theta dF_1(\theta)}{1-F_1(0)} < -\frac{\int_{\theta>0}\theta dF_0(\theta)}{1-F_0(0)}, \quad \text{ie,} \quad \frac{1-F_1(0)}{1-F_0(0)} < \frac{-\int_{\theta>0}\theta dF_1(\theta)}{-\int_{\theta>0}\theta dF_0(\theta)}. \tag{1.24}$$

To see that this condition is always satisfied, let $(1-F_1(0))/(1-F_0(0)) \equiv (1/x =)y > 1$. Moreover, note that

$$\int_{\theta>0}\theta dF_1(\theta) \geq \int_{\theta>0}\theta y dF_0(\theta) = y\int_{\theta>0}\theta dF_0(\theta). \tag{1.25}$$

[11] To be more precise, this is true (and the above property applies with strict inequality) whenever the MLRP conditions are satisfied with strict inequality at least for some payoff outcomes $\theta \leq \hat{\theta}$.

Combining these properties, one obtains

$$\frac{1-F_1(0)}{1-F_0(0)} = y \leq \frac{-\int_{\theta>0}\theta dF_1(\theta)}{-\int_{\theta>0}\theta dF_0(\theta)}(\geq y). \tag{1.26}$$

The previous analysis allows us to state:

Proposition 2. *Consider distribution functions F_0, F_1 such that $F_1(\theta)$ dominates $F_0(\theta)$ according to the MLRP. If the payoff distribution changes from F_0 to F_1, expected payoffs θ^E increase so that c^* falls. Moreover,*

(1) $\tilde{c}(>0)$ falls so that P delegates less *often when externalities are positive.*

(2) $\dot{c}(<0)$ falls so that P delegates more *often when externalities are negative.*

Suppose the distribution function improves in a way that not only the expected payoff θ^E increases, but also the MLRP applies. Regardless of whether or not P decides to delegate, her expected utility from undertaking the project increases. Under P-authority, this payoff change equals the change in θ^E whenever $c > c^*$, that is, whenever P is in favor of project completion (and her payoff change is zero otherwise). Under A-authority and again for $c > c^*$, the principal benefits from an interplay of two effects: first, as A undertakes the project whenever it has positive payoffs and the more favorable distribution F_1 increases the likelihood of this event, P more often incurs those externalities.[12] Second, as the MLR property shifts weights towards larger payoff realizations in a monotonic way, the expected payoff value of positive outcomes increases.

In the light of these tradeoffs, our result shows that when externalities are positive, the increase in θ^E, always dominates those two effects under agent authority, when the MLRP applies. Intuitively, the upper threshold $\tilde{c}$ falls because the F_1 distribution takes substantial weight away from negative payoff outcomes. This strongly benefits the principal under P authority who cannot base his project decision on observed project values.[13] Under MLRP, this effect overcompensates for the agent's increased likelihood of undertaking the project, and the associated increase in externality benefits for the principal.

The fall in the lower boundary of the delegation range $\dot{c}$ when the payoff distribution improves, rests on a different logic. The change in the distribution now does not change U_P^P, because in the relevant range $c < \theta^*$, the principal does not undertake the project. However, two effects change U_P^A when externalities are negative. First, and as before, P benefits from a higher likelihood of positive payoffs $\theta > 0$. On the other hand, A now undertakes the project more often and in consequence, inflicts a negative externality $c < 0$ on the principal.

[12] As $\tilde{c}$ is always positive, this effect is payoff-positive at the margin of the delegation range even if $c^* < 0$.

[13] Conversely, note that the principal's utility boost from the increase likelihood of outcomes $\theta > 0$ is identical across authority regimes.

As we show, under the MLRP this tradeoff is resolved in favor of the former effect: even though $c < 0$, agent authority benefits the principal more when the payoff distribution improves. Hence, the range of negative externalities for which delegation becomes optimal expands.

To summarize, we have established that under conditions which are satisfied by many commonly used distribution functions, 'better' payoff distributions and the resulting increase in expected payoffs, causes P to narrow down the range of externalities for which she finds delegation beneficial when the project causes a positive externality. However, the opposite is true when externalities are negative. In other words, more beneficial project payoffs will make P more hesitant to delegate in circumstances where she is willing to undertake the project herself, whereas the same payoff change makes her more prone to delegate when she herself is willing to forgo the project.

Reverse results are attained when the distribution of payoffs moves into a less favorable direction. Perhaps interestingly, our results suggest that for this case, a principal who is prone to start the project in own authority, will now delegate more often than before. When payoffs worsen, flying blind becomes more risky and the principal has a stronger motive to exploit the agent's payoff information. Hence, agent authority becomes more attractive.

1.5 Payoff sharing

We now consider a situation in which P and A share the project payoff θ under a linear sharing contract where $\alpha \in (0,1)$ is the agent's share. For example, the agent may be a division manager who under the terms of his labor contract, is entitled to a share of division profits. Under these circumstance, the utilities of both parties (conditional on project realization) become

$$U^A = \alpha\theta, \qquad U^P = (1-\alpha)\theta + c. \tag{1.27}$$

Since $\alpha > 0$, a change in the agent's payoff share does not affect his decision rule, which remains $x_A = 1$ whenever $\theta \geq 0$. In contrast, the principal now undertakes the project whenever $c \geq c^* \equiv -(1-\alpha)\theta^E$. Specifically, a larger α leads the principal to lower the threshold externality level c^* beyond which she decides to implement the project if she has authority, in asymmetric ways: if the project has a negative payoff expectation so that $c^* > 0$, c^* falls in response to an increase in α. In a way, the principal's reduced payoff share partially protects P from the negative payoff expectation, and undertaking the project becomes more attractive. The opposite is true if θ^E is positive, so that $c^* < 0$. In this latter case, an increase in α lowers P's expected payoff from the project, so that the threshold externality increases and moves closer to zero.

We can now analyze how a change in α affects the principal's willingness to delegate authority to the agent. Notice that U_A^P falls in α at a rate of $\Delta\alpha \int_{\theta>0} \theta dF\theta > 0$. In contrast, for $c^* > 0$, U_P^P falls at a rate of $\Delta\alpha\theta^E$ when $\theta^E > 0$, and increases in α at a rate of $-\Delta\alpha\theta^E$ when expected project payoffs are negative, $\theta^E < 0$. Accordingly, with

$$\tilde{c}(\alpha) = -\frac{(1-\alpha)\int_{\theta<0}\theta dF(\theta)}{F(0)}, \tag{1.28}$$

the derivative yields

$$\frac{d\tilde{c}(\alpha)}{d\alpha} = \frac{\int_{\theta<0}\theta dF(\theta)}{F(0)} < 0. \tag{1.29}$$

Similarly, one can show that $\dot{c}(\alpha)$ increases in α. To see this, it is sufficient to remember that $U_P^P(\alpha) = 0$ at $c = \dot{c}(\alpha)(< 0)$, that $U_A^P(\alpha)$ falls in α, and that $U_A^P(\alpha)/dc = 1 - F(0)$ is independent of α.

We can now state

Proposition 3. *Let α be the agent's payoff share. As α increases, $\tilde{c}(\alpha)$ falls and $\dot{c}(\alpha)$ increases. Hence, the delegation range of externalities $(\dot{c}, \tilde{c})$ shrinks for positive and negative externalities. Moreover, whenever $\theta^E < 0$, any increase in α (starting at some α_0) strictly increases P's utility for any $c > \tilde{c}(\alpha_0)$ where P retains authority and undertakes the project.*

The final result of the Proposition 1.5 is counterintuitive and possibly surprising. Suppose that expected project payoffs θ^E are negative, so that $c^*(\alpha) > 0$. In this case, an increase in α lessens P's payoff loss when (for $c > c^*$) she chooses to undertake the project. The principal's expected utility under P authority therefore increases in α while at the same time, her utility clearly shrinks under agent authority where the project is realized only if payoffs are positive. As a consequence, a larger α not only makes delegation less attractive, but offering a larger payoff share to the agent enhances P's utility if she retains authority. Over the relevant range of positive externalities, P wishes to concede *all* payoffs to the agent, while *not* delegating authority to A. Notice that as θ^E is negative, at the same time the agent *loses* when his payoff share α increases and $c > \tilde{c}(> 0)$.

For a scenario where $\theta^E > 0$, the logic is different. Now, an increase in α makes P suffer both under agent authority (for the same reason as before), and under P-authority, as her payoff falls because expected project payoffs are positive. As it turns out, the former loss dominates the latter, and the delegation range shrinks even in this case where externalities are negative.

1.6 Concluding Remarks

In this paper, we have looked at the delegation problem of a firm owner/manager, who can decide whether or not to delegate the decision on a particular project to the agent (leader of the team working on that particular project). Where the information on the project payoff is exogenous, the manager can resolve any conflict of interest between herself and the agent, by trying to hire an agent mimicking her own preferences. Although in this model, principal and agent have a common goal (manifesting itself through parameter θ), in reality it is not unreasonable to assume that the principal has more to consider than the fate of this single project in isolation, as the completion of a project may affect the other parts of the firm through externalities. It is also reasonable to assume that the agent has a more thorough understanding of the true project's payoff, while the principal may only know the distribution. The existence of asymmetric information (and externalities) will prohibit the principal from delegating the project to the agent and taking a back-seat herself in all situations.

We show that when the project can produce strong negative or positive externalities for the whole company, the manager prefers to retain control over the project in order to avoid missed opportunities or possible disasters. More specifically, we show that the delegation is limited to a range of externalities around zero. If negative outcomes are often severe, whereas positive outcomes are more moderate, the principal will delegate more often when externalities are positive, compared to when they are negative (and vice versa).

When the payoffs improve (we move to a new payoff distribution that likelihood-ratio dominates the old distribution), the improved project payoffs makes the delegation less likely when the principal is willing to undertake the project herself, and more likely when she is willing to forgo the project. This suggests that when the economic outlook of a business division with positive externalities brightens, upper management may find delegation less attractive, preferring a more centralized corporate structure. Conversely, the delegation range expands, if project externalities for the parent company are negative.

Lastly, we have shown that if principal and agent share the project payoffs according to some balanced sharing rule, the principal may strictly benefit from allowing the agent a larger payoff share. When expected project payoffs are negative, but externalities are positive, payoff sharing while retaining authority, acts as an insurance device against negative payoff shocks for the principal, while at the same time allowing her to reap the externalities that the project generates for the company as a whole. With payoff sharing, the manager delegates the authority to the team leader less often, both for positive and negative externalities.

In conclusion, we believe this simple model has the potential to pave the way for future empirical work on delegation in companies where the fast pace of the market requires agile decision making and hence inevitable delegation of some projects, in an environment where decisions of single divisions affects companies as a whole.

Chapter 2

Public Funding of In Vitro Fertilization and Multiple Births

Abstract

In this paper, I study the effects of covering in vitro fertilization (IVF) expenses under public health insurance on multiple birth rates in Canada. The coverage increases the access to these services and the use of IVF and other assisted reproductive technologies in treating infertility has been known to result in higher rates of multiple pregnancy. My results provide little evidence that the coverage of IVF costs by public healthcare plans led to any significant increase in multiple birth rates. On the contrary, the point estimates indicate that the coverage may have resulted in up to 330 fewer multiple births per 100,000 live births. The responsible mechanisms for such a decline can be mandates by public health bodies on the number of embryos that can be transferred in one cycle, and the lower pressure on the patients to transfer multiple embryos for maximum chance of success.

Keywords: delegation; program evaluation; population control policy; public health policy; fertility

2.1 Introduction

It is estimated that 11.5% to 15.7% of the Canadian married and common-law couples with a female partner aged 18–44 struggle with infertility. Approximately 15% of these infertile couples seek medical help (Bushnik et al. (2012)).[1] The use of in vitro fertilization (IVF) and other Assisted Reproductive Technologies (ARTs) in treating infertility can result in higher rates of multiple pregnancies (See Kiely and Kiely (2001) and Martin and Park (1999) for example).[2]

In this paper, I study the effects of covering IVF expenses under public health insurance on multiple birth rates in Canada. IVF can be very expensive. One cycle of IVF can cost anywhere between \$10,000 and \$20,000, depending on where the procedure is performed. Patients are therefore inclined to opt for multiple embryo transfers in a single cycle, to avoid extra costs and to increase the chance of a successful pregnancy, which can result in multiple births (Reynolds et al. (2003), Angard (2000) and Elster (2000)). Multiple pregnancies, however, are associated with:

- greater risk of pre-mature births and lower birth weights (Alexander et al. (1998)),
- 5-10 times higher risk of cerebral palsy (Pharoah (2006)), and
- 5-20 times higher health-care expenses for twins and births of the third order and up, respectively, compared to the cost of single pregnancies (Lemos et al. (2013)).

Any decision on public funding of IVF therefore must consider that: (a) funding of IVF under public health plans is costly and comes unavoidably at the expense of cuts to other government funded services (assuming no increase in taxes); and (b) the increase in multiple births associated with greater number of IVF cycles adds substantial costs to the healthcare system. The first point has been the subject of many heated debates (See Baylis (2013) for example). However, in this paper, I am going to focus on the second point, as it is very important for policy makers to have a clear understanding of the effects public funding of IVF may have on multiple birth rates.

As coverage of infertility treatment services under insurance plans increases access to those services, one expects to see higher usage of infertility treatment services when insured. Bitler and Schmidt (2012) and Bundorf et al. (2007) found that in the US, mandates that require insurance plans to cover infertility treatments have a significant and positive effect

[1] Public Health Agency of Canada (2019) defines infertility as lack of conception after one year of sexual intercourse without contraception for women under 35 years, and 6 months for women over 35 years.

[2] Health Quality Ontario (2006) estimated the rate of multiple pregnancy resulting from IVF in Canada to be around 30% in 2006. The rate has since declined considerably (to 10.1% in 2014, the last year for which data is available from Canadian Fertility and Andrology Society (2016)). For comparison, multiple birth rate for general public in Canada was about 3.15% in 2006 and 3.29% in Canada in 2014 (Statistics Canada (2021*b*)).

on utilization of those services. On the other hand, if mandates restrict the number of embryos that can be transferred in one cycle of IVF, fewer multiple births occur as a result of IVF in mandate states (Henne and Bundorf (2008) and Reynolds et al. (2003)). Therefore public funding of IVF leading to an increase or a decrease in the multiple births resulting from IVF greatly depends on the mechanisms laid down by the lawmaker.

Buckles (2013) studies the impact of mandates that require insurance companies to cover infertility treatments in the US on multiple birth rates. She finds that these mandates have a small and statistically insignificant effect on multiple birth rates and that the increase in multiple birth rates are only observed for women over 30. Married women, white women, and those who have a college degree have experienced a greater increase in multiple birth rates.

Assuming that public funding of IVF grants access to those who didn't consider IVF as an option due to costs in Canada, one may expect higher multiple birth rates after some kind of reimbursement for costs was introduced. However, my results show little evidence of any significant increase in multiple birth rates due to public funding IVF costs. Partial coverage of IVF may have negated that effect of higher access via one or more of the following mechanisms:

1. Regulations to limit number of transferred embryos were introduced in 2010 in Quebec and 2015 in Ontario. In 2006, Joint Society of Obstetricians and Gynaecologists of Canada - Canadian Fertility and Andrology Society Clinical Practice Guidelines Committee issued "Guidelines for the Number of Embryos to Transfer Following In Vitro Fertilization" which recommended the number of embryos transferred to be no more than two (Min et al. (2006)). In 2010, the same committee issued "Elective Single Embryo Transfer Following In Vitro Fertilization" which asked practitioners to explain the risks of double embryo transfer to patients and perform elective single embryo transfers in patients with good prognosis (Min et al. (2010)). These guidelines only offered recommendations and were not mandatory to follow in all clinics. Nevertheless, part of the reduction in multiple births in Canada after 2010, may be a result of mandates for single embryo transfer in Quebec and Ontario or the guideline issued by Canadian Fertility and Andrology Society.

2. The success rate of ARTs have consistently increased through the years. As probability of a successful IVF cycle goes up, patients will be less willing to take the risk of multiple pregnancy and may elect single embryo transfer, even in the absence of single embryo transfer mandates.

3. Partial coverage of IVF costs may have lifted the pressure off patients to transfer as many embryos as possible in a single IVF round to maximize their chances of getting pregnant the first time.

Table 2.1 shows the number of total IVF/ICSI (Intracyptoplasmic Sperm Injection) cycles performed in Canada, as well as fraction of cycles with no more than two embryos transferred, singleton live births rates per cycle, multiple delivery rate per delivery and triplet or more rate per delivery in years 2001, 2003, 2005 and 2007. Data comes from annual reports from Canadian Assisted Reproductive Technology Register (CARTR) which collects treatment cycle data from Canadian fertility centres which offer ARTs. We are using 2004 and 2007 cycle reports (Gunby et al. (2008, 2011)).[3]

Table 2.1: IVF/ICSI cycle outcomes from CARTR for different years

Outcome	**2001**	**2003**	**2005**	**2007**
No. of clinics participating (%)	19 (86%)	24 (100%)	25 (100%)	26 (100%)
No. of IVF/ICSI cycles reported	5393	7535	8195	8972
Cycles with 1 or 2 embryos transferred (%)	49%	65%	68%	69%
Clinical pregnancy rate per cycle (%)	28.3%	31.2%	32.10%	35.6%
Live birth rate per cycle (%)	23.1%	23.9%	25.60%	28.6%
Singleton live birth rate per cycle	15.5%	16.5%	17.70%	20.0%
Multiple delivery rate per delivery (%)	32.8%	31.3%	30.80%	30.2%
Triplet or more rate per delivery (%)	2.7%	1.6%	1.40%	1.1%

Note: CARTR = Canadian ART Register; IVF = in vitro fertilization; ICSI = intracytoplasmic sperm injection

This is a partial recreation of Table 5 in Gunby er al. 2004 and Table 4 in Gunby et al. 2007.

As Table 2.1 suggests, not only percentage of all cycles with no more than two transferred embryos has increased from 2001 to 2007, but also pregnancy rate per cycle and live birth rate per cycle have increased in the same time period. This is consistent with the mechanisms mentioned above.

Also, a single embryo transfer policy (although highly successful in lowering multiple birth rates) may not be necessarily successful in lowering the costs imposed on the healthcare system, without setting proper access restrictions and age limits.[4]

Mr results are consistent with what Buckles (2013) found in the US. However, as Statistics Canada (2021*b*) only provides aggregate data on number and type of births, and nothing on mother's characteristics, I cannot refine these results any further.

[3]CARTR has changed the format of their reports after 2011, and these information are not readily available for more recent years.

[4]Of all children conceived through ARTs in Quebec, the proportion of newborns from multiple pregnancies has substantially decreased by 55% from 38.5% in 2009 to just over 17% in 2013 (Canadian Fertility Andrology Society (2014)). However the cost of program which was estimated to be $30,000,000 in 2010-2011, ended up close to $70,000,000 in 2013-14 (CBC (2015)).

2.2 Multiple Births and IVF Coverage in Canada

Figure 2.1 shows multiple birth rates for different provinces in Canada from 1991 to 2019. Data is extracted from Statistics Canada (2021*b*).

Multiple birth rates have gradually risen over the years. This is not a phenomenon limited to Canada. Other countries have been experiencing a similar increase in the rate of multiple pregnancies (For example, see Steegers-Theunissen et al. (1998) and Martin et al. (2012)). Reasons include increasing maternal age, advancements in infertility treatments and introduction of assisted reproductive technologies (Black and Bhattacharya (2010)). The most common of these assisted reproductive technologies is in vitro fertilization (IVF).

IVF consists of different steps: ovarian stimulation, egg retrieval, fertilization, and embryo transfer. As the IVF procedure can be inefficient, ovarian stimulation is performed to make retrieval of multiple oocytes in a single cycle possible. Retrieved eggs are then fertilized in a culture dish and in the last step, the resulting embryos (if any) will be transferred back into the uterus. To maximize the chance of success with minimum number of trials, some patients may decide to transfer multiple embryos, which results is much higher rates of multiple pregnancies among IVF users. In this paper, I specifically focus on the link between easier access to IVF and increase in the rate of multiple pregnancies in Canada.

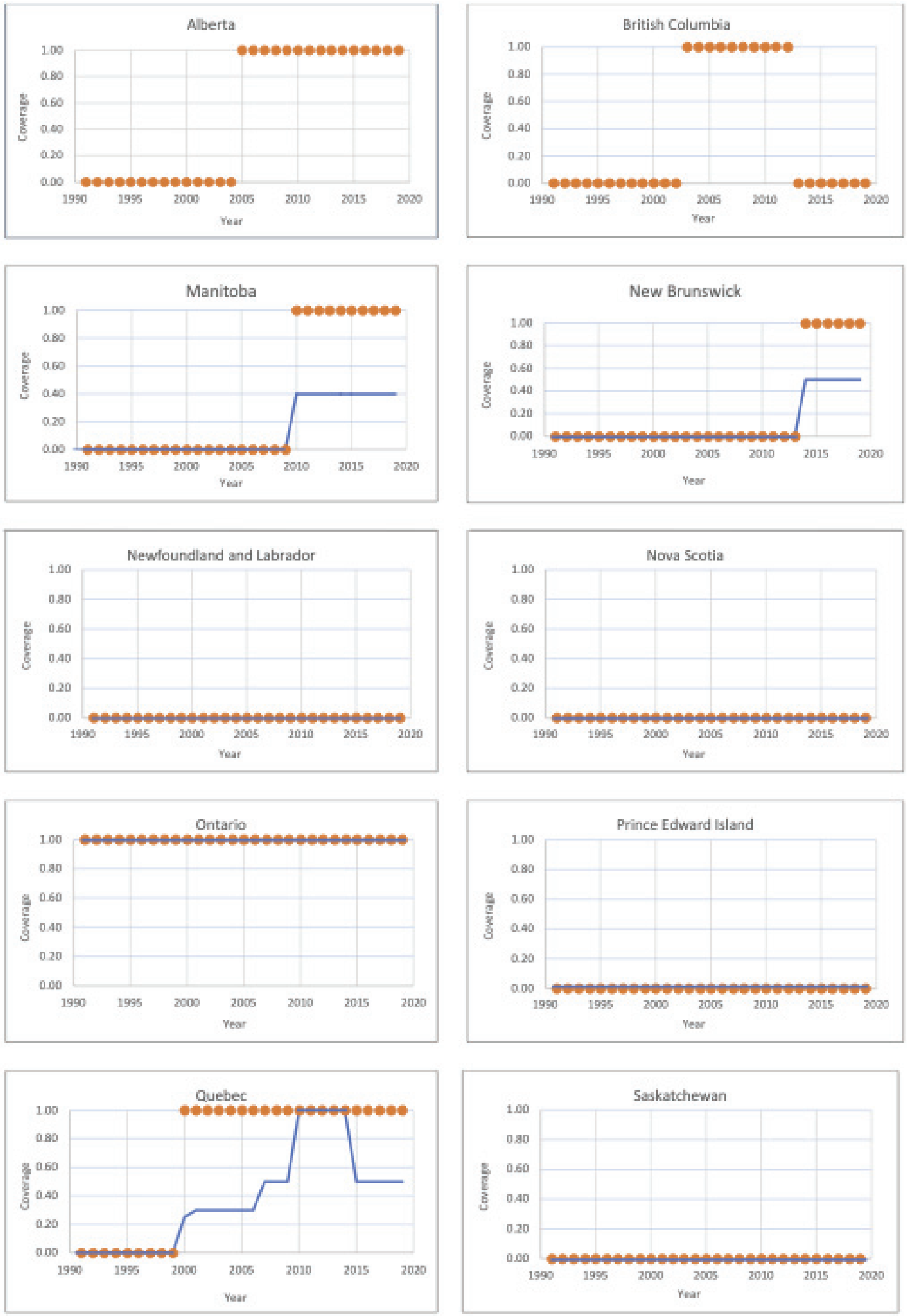
Figure 2.2 summarizes the status of public coverage of IVF expenses for different provinces from 1991 to 2019. The solid line shows the portion of IVF expenses covered by public health plans and these levels are what I am using as values for my continuous policy variable (C_{it}) in Section 2.3, when trying to estimate the effects of IVF coverage on multiple birth rates. Alberta and British Columbia had fertility funds in place at points in time, but these funds were income-restricted and not accessible by the whole public. Hence, there are no lines in graphs drawn for these two provinces. The red dots indicate whether a province had any measure in place in any given year or not. These are the values I use for my binary policy variable in Section 2.3, where $C_{it} = 1$ in the former case, and $C_{it} = 0$ in the latter case.

The first successful IVF cycle in Canada was completed in 1982 with the birth of twin boys. In 1983, Ontario became the first Canadian province to cover up to a maximum of three cycles of IVF under public health insurance, for all types of infertility and without any limitations on the number of transferred embryos. Since then, more provinces have started to cover in vitro fertilization under public healthcare system, however the conditions and the extent of coverage differs from province to province.

In 1993, a report by a joint panel of the Ontario Ministry of Health and the Ontario Medical Association resulted in delisting of IVF from the services covered by Ontario Health Insurance Plan (OHIP), except for a very specific type of infertility. From 1994, OHIP began covering three “fresh" cycles of IVF, only for women younger than 40 with both Fallopian

Figure 2.1: Multiple birth rates in different Canadian provinces

Figure 2.2: Portion of IVF expenses covered by public health plans



The solid line shows the portion of IVF expenses covered by public health plans in different years. Alberta and British Columbia are excluded as they had fertility funds in place at points in time, but these funds were income-restricted and granted on a case to case basis. The red dots indicate whether a province had any measure in place in any given year or not.

tubes blocked/missing, excluding the cost of drugs[5]. No restrictions were placed on the number of embryos transferred. From December 2015, Ontario expanded access to IVF services to one IVF cycle per eligible patient per lifetime. The program is limited to women of up to 42 years of age and men who require surgical sperm retrieval and would require one-at-a-time transfer of all viable embryos (to allow for the possibility of multiple chances for pregnancy). Cost of drugs and associated services (like embryo storage) must be paid by the patient.

Quebec began funding IVF in 2000 with a tax credit of up to 25% (or up to $15,000) for eligible fertility treatments. The tax credit raised to 30% (up to $20,000) in 2001 to 50% (or up to $20,000) in 2007. The province extended funding of IVF in August 2010 to complete coverage of costs for three stimulated or six natural cycles for all women of child-bearing age (with no upper age limit), conditional on a single embryo transfer per cycle[6]. Due to unexpectedly high costs of the program, in 2015 the Quebec government removed coverage for in vitro fertilization except in cases of egg/embryo freezing for cancer and replaced it with a tax credit mechanism (20% to 80% up to a maximum of $20,000) based on family income for eligible patients (no prior children, vasectomy or tubal ligation). The program requires single embryo transfer for women age 36 and younger, and no more than 2 embryos in women age 37 or older.

Alberta and British Columbia do not cover IVF expenses under public health insurance. However in Alberta, those unable to afford IVF treatments who can show adequate need for financial support can apply for financial assistance from "Generations of Hope Fertility Assistance Fund", established in 2005[7]. A similar fund was active in BC from 2003 to 2012 (Rowe (2012)).

In Manitoba, a Fertility Treatment Tax Credit equal to 40% of fertility treatment fees (up to $8000) can be used towards the cost of infertility treatment (including IVF), as of October 1, 2010 . In New Brunswick, couples who have received infertility treatment after April 1, 2014 are eligible to apply for a one-time grant for up to 50% of eligible incurred costs of IVF (up to $5,000). There are no mandated limits on the number of embryos transferred in Manitoba or New Brunswick.

Prince Edwards Island has started a fertility support program, effective January 1, 2021, to provide funding to residents accessing IVF. The program provides $5,000 to $10,000 annually (based on family income), for up to three years.

[5]Cost of drugs is estimated to be $5000 per cycle of IVF.

[6]Under certain conditions, the physician could transfer a maximum of 2 embryos if the woman was 36 years of age or younger, and a maximum of 3 embryos if the woman was 37 years of age or older.

[7]Generations of Hope: Fertility Assistance Fund. Retrieved 2015, November 22 from http://www.generationsofhope.ca/

Newfoundland and Labrador, Nova Scotia, and Saskatchewan have never covered IVF under public health insurance. Appendix A summarizes the state of IVF coverage in different provinces over time.

In the next section, I am going to use the variations in pubic coverage of IVF expenses across Canadian provinces over time, to estimate the effect of this coverage on multiple birth rates.

2.3 Methodology and Data

2.3.1 Empirical Model

To determine whether public funding of IVF affects multiple birth rates, I use a standard difference-in-difference model. The main assumption behind this model is that as IVF is associated with higher multiple birth rates, resulting from potential multiple embryo transfers, one expects to see higher multiple birth rates in provinces where a bigger ratio of IVF expenses are covered by government, compared to those with no/less coverage, conditional on nothing else being different. This is the case if coverage of IVF expenses under public health insurance causes a significant change in the number of people using IVF as a treatment for infertility. Let:

$$Y_{it} = \alpha + \gamma_i + \delta_t + X_{it}\beta + C_{it}\theta + \epsilon_{it}, \tag{2.1}$$

where Y_{it}, the outcome of interest, is the multiple birth rate in province i in year t. Province and time fixed effects are γ and δ, respectively. My policy variable, C_{it}, is a dummy variable that indicates whether IVF costs are covered (partially or fully) in province i in year t. C_{it} can also easily be modified to account for the fact that IVF coverage mandates in Canada are not uniform in the level of coverage. In this case, the continuous policy variable, C_{it}, is a measure of the fraction of costs which are covered by public healthcare plans. For example, $C_{it} = 0.5$ for Quebec in 2008.

Fertility behavior is known to be affected by macroeconomic conditions (see Buckles et al. (2021) for example). This is why I introduce controls for province-level economic conditions. Matrix X in Equation (2.1) contains a set of province level controls. I include a control for unemployment rate, inflation, and median income of people aged 16 years or more (in 2019 constant dollars).

I also present the results without province population weights in Section 2.4, to make sure that the results are not derived solely by the variation in coverage observed for Quebec and Ontario, as these two provinces are the two with biggest populations in Canada, and most of the variation in the continuous policy variable comes from Quebec. Results for regressions weighted by province population are reported in Appendix B.

There are some other issues that need to be considered:

1. British Columbia and Alberta had fertility funds in place which helped families in need of financial assistance (BC from 2003 to 2012 and Alberta since 2005). As I don't have enough data to verify what percentage of the costs were reimbursed for which group of patients, I have excluded these two provinces from the data in Section 2.4 estimations. Appendix C, however, shows the results for the specification with binary treatment variable $C_{it} = 1$ for BC between 2003 and 2012 and Alberta after 2005.

2. Quebec has implemented an income-based tax credit for IVF since 2015. The tax credit ranges from 20% to 80%. The results in Table 2.4 are reported for $C_{it} = 0.5$ for Quebec after 2015. Appendix D reports the result of the regression for different values of C_{it} for Quebec after 2015. For reference, Quebec's median family income for 2015-2019 has varied between \$75,530 and \$87,080, corresponding to tax credits of between 53% and 62% (Revenue Quebec (2020)).

3. As shown in Figure A.1, $C_{it} = 1$ for Ontario all along. However, the coverage in 1992 (full coverage) is very different from 2010 (full coverage for up to three cycles only for women with blocked Fallopian tubes) or 2019 (full coverage for only one cycle). As is often in the case of empirical work, this complex multidimensional policy is simplified by using a scalar variable– a limitation in the scope of the policy measure.

Last, but not least, I report the results for two periods: first, 1991–2019, and second, 2000–2019, when provinces other than Ontario started partially covering IVF expenses.

2.3.2 Data

In this paper, I use Statistics Canada (2021*b*) data on live births and fetal deaths from 1991 to 2019 to construct the dependent variable (multiple birth rate) when estimating the effect of public funding of IVF on multiple birth rates. Unit of observation is province-year. This data allows us to track differences in multiple birth rates between provinces with IVF coverage and those without. However, it also poses some challenge: First, as Canadian vital statistics data does not report any information about the parents, I am not able to narrow the results for different socioeconomic groups. Second, the coverage in different provinces varies for different age groups and are for a given number of cycles, which also may vary among provinces. Although my policy variable has limitations in capturing these differences, it can be interpreted as an "average" of the policies in place in those provinces.

I use Statistics Canada (2021*c*) data on population of each province in 2010 to construct population weights for my weighted regressions. For provincial control variables, I use Statistics Canada (2021*a*, 2022*a*,*b*) data to find median income of people older than 15 (in 2019 constant dollars), unemployment rate for the age group of 15 years and over, and inflation based on not-seasonally-adjusted CPI for each province in each year. Table 2.2 presents the summary statistics for the variables in my model.

Table 2.2: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Multiple Births per 100K Live Births	2806.37	504.73	1297.30	4392.59
Unemployment Rate	8.90	3.53	3.40	20.10
Inflation	1.98	1.16	-1.25	7.53
Median Income (16+)	30947.24	4912.09	20700	43900

Notes: Number of observations = 290.

I report the results in the next section.

2.4 Results

My results on the effects of public funding of IVF on multiple births for the binary policy variable are reported in Table 2.3. All regressions include province and year fixed effects. To be exact, the dummy variable is equal to one for Manitoba after 2010, New Brunswick after 2014, Ontario between 1991 and 2019, and Quebec after 2000. Alberta and BC are excluded from the data, due to the coverage not being available to all patients. Results with Alberta and BC being part of the data is presented in Appendix C. Columns 1–3 in Table 2.3 show the results for the whole period of 1991–2019, while columns 4–6 report the results for the period after 2000, when more provinces started partially covering IVF expenses.

Columns 1, 3, 5, and 6 in Table 2.3 report the result for the difference-in-difference model specified in Equation (2.1). Based on these results, it is hard to say if IVF coverage in public insurance has had any effects on multiple births. The coefficient of interest is presumably negative, but small and statistically insignificant. The point estimates indicate that IVF coverage reduces multiple births by 131 in 100,000 live births. For Ontario, for example, which has had between 120,000 and 150,000 live births per year in the past 20 years, this translates to 155-195 fewer multiple births per year. The results seem robust to inclusion of provincial indicators like unemployment rate, inflation, and median income. However, the effect is even smaller at 119 fewer multiple births per 100,000 live births when controlling for province-level economic conditions.

Limiting the timeline to the years after 2000, the coefficient of interest becomes positive. Although it is very small and statistically insignificant, both with provincial controls and without them. The point estimates practically shows that coverage of IVF expenses has led to about 20 more multiple births in 100,000 live births.

While policy evaluation using difference-in-difference models are common practice, recent research indicates that that two-way fixed effect (TWFE) models, like Equation (2.1), produce unbised estimations if treatment effect is constant across groups and over time (De Chaisemartin and d'Haultfoeuille (2022); Roth et al. (2022)). This condition does not hold in my model. As De Chaisemartin and d'Haultfoeuille (2022) and Roth et al. (2022), among others, point out, TWFE regressions are not robust to heterogeneous treatment effects and can induce sign reversals of the estimated coefficients. The TWFE model results can be understood as a weighted average of treatment effects, and the problem is that some of those weights can be negative. If the largest treatment effects happen to be the ones that get negative weights, the TWFE estimator can produce a negative average treatment effect on the treated (ATT), even when all of its components are positive (and vice versa).

Columns 2 and 4 in Table 2.3 show the results of my binary regression model, using the alternative heterogeneity-robust difference-in-difference estimator developed by De Chaisemartin and d'Haultfoeuille (2022). Although these results are noisier (bigger standard

Table 2.3: Effect of IVF coverage by public health plans on multiple births - binary policy variable

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES		1991-2019			2000-2019	
IVF Coverage (C_{it})	-131.3	6.29	-119.9	0.769	-72.17	22.32
	(105.5)	(272.4)	(93.08)	(133.8)	(197.1)	(113.0)
Unemployment Rate			-33.03			-8.206
			(24.54)			(34.73)
Inflation			34.05			-75.98*
			(27.90)			(37.47)
Income			-0.0101			0.0201
			(0.0129)			(0.0137)
Observations	232	232	232	160	160	160
R-squared	0.706		0.710	0.373		0.389

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Dependent variable is multiple births per 100,000 live births. Policy variable is whether a province had any policy in place to partially or totally cover IVF expenses. All regressions include province and year effects. Alberta and BC are excluded from the data.

errors), they are consistent with the findings of my main regression. We cannot tell if coverage of IVF in public insurance has had any effects on multiple births.

Tables B.1 and B.2 in Appendix B show my estimates for regressions weighted by province populations in year 2010, for cases where Alberta and BC are included in/excluded from the data. The coefficient on the policy variable is statistically significant when I consider years 1991–2019, but not when I limit the timeline to 2000–2019. These results hold true when we add provincial controls. Under this specification, public coverage of IVF seems to be responsible for 120–200 fewer multiple births per 100,000 live births. This is the only specification where the policy variable is significant, though the result is more than likely to be driven by the coverage in Ontario (province with highest population).

Next, I present the results for the main specification with a continuous policy variable in Table 2.4. C_{it} is the proportion of IVF costs that are covered by public health plans in each province in each year. Columns 1 and 2 in Table 2.3 show the results for 1991–2019, and columns 3 and 4 report the results for 2000–2019. The estimates in this table are not weighted by province population. However, the weighted estimates are reported in Table B.3 in Appendix B. The province of Quebec has started offering an income-based tax credit of 20% to 80% for IVF treatment since 2015. In these regressions, I have used 50% for the value of the policy variable between 2015 and 2019. Appendix D shows the results for 20%, 40%, 60%, and 80% tax credit.

Without including the provincial population weights, the coefficient of interest is statistically insignificant, both with provincial control variables and without them. The effect of public insurance coverage of IVF on multiple births is indeterminate and varies with the

Table 2.4: Effect of IVF coverage by public health plans on multiple births - continuous policy variable

	(1)	(2)	(3)	(4)
VARIABLES	1991-2019		2000-2019	
IVF Coverage (C_{it})	-229.4	-236.2	-48.52	3.155
	(169.4)	(160.1)	(188.2)	(162.1)
Unemployment_Rate		-36.70		-6.474
		(23.49)		(36.77)
Inflation		33.09		-74.75*
		(28.12)		(37.93)
Income		-0.0130		0.0207
		(0.0118)		(0.0142)
Observations	232	232	160	160
R-squared	0.705	0.711	0.373	0.389

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Dependent variable is multiple births per 100,000 live births. Policy variable is the proportion of IVF expenses that are covered by public health plans. All regressions include province and year effects. Alberta and BC are excluded from the data.

choice of timeline. IVF coverage can be interpreted to reduce multiple births by 229 in 100,000 live births. For Ontario, for example, this translates to about 350 fewer multiple births per year (at most).

Table B.3 in Appendix B shows my results of the regressions with continuous policy variable, weighted by province populations in year 2010. The coefficient on the policy variable is statistically significant for years 1991–2019, with or without provincial control variables. Under this specification, the point estimates indicate that public coverage of IVF seems to be responsible for 290–327 fewer multiple births per 100,000 live births. The significance of policy variable in weighted regressions is possibly the result of the higher weight of Ontario, compared to other provinces. When we limit the years to those after 2000, the effect becomes smaller (about 175 fewer multiple births per 100,000 live births) and insignificant.

2.5 Concluding Remarks

In this paper I have studied the effect of coverage of IVF costs under public health plans on the rate of multiple births in Canada. I have used the variation in coverage, across different provinces and over time, in a difference-in-difference model to estimate the change in multiple birth rates.

The results presented in Section 2.4 provide little evidence that the coverage of IVF costs by public healthcare plans led to any significant increase in multiple birth rates. This may be attributed to mandates requiring single embryo transfer in each cycle of IVF, technology advancements leading to increased success rates for IVF and lowering the need for multiple embryo transfers, and/or decreased pressure on people seeking treatment to transfer multiple embryos due to the costs being fully/partially reimbursed, even in the absence regulations on the maximum number of embryos transferred. The results are robust to different specifications of the policy variable and different timelines.

I believe the question this paper is trying to answer is an important one for the policy-makers in Canada, not only because public coverage of IVF may come at the cost of losing coverage for some other services, but also because multiple birth rates associated with ARTs impose high costs on the public health. No matter if the result is higher or lower birth rates (due to increase in access or single embryo transfer mandates), understanding the role coverage of IVF plays is essential. Although, not having access to the IVF patients' data, I could not refine my results by the mother's characteristic, I believe further studies doing so are important to make sure that future IVF coverage policies support those seeking treatment, without inflicting extra costs on the healthcare system.

Chapter 3

The Role of Financial Incentives in the Decline of Population Growth Rate

Abstract

There has been a long debate among economists and policy makers over the effectiveness of population planning programs. The estimated program effects in the literature vary substantially. One such program is the Iranian 1993 Population Control Law that withdrew paid maternity leave and social welfare subsidies in the case of children of fourth and higher parities. We use data from publicly available sample of 2006 Iranian census and the annual Household Expenditure and Income Surveys (HEIS: 1988-2005) to estimate the effect of this policy on fertility outcomes. Our difference in difference method compares the change in probability of having a birth in families with fewer than three children prior to the legislation to the change in probability of having a birth in families with three or more children. We find that the legislation had a modest effect of 8 to 13 percent on decreasing the probability of a fourth or higher birth. The law has the highest impact after four years of implementation and effect size gradually vanishes after that.[1]

Keywords: delegation; program evaluation; population control policy; public health policy; fertility

[1] This paper is co-authored by Reza Sattari and I.

3.1 Introduction

High population growth rates (or as a closely related parameter, high total fertility rates) are generally deemed undesirable by economists and politicians alike. Becker (1960) and Becker and Lewis (1974) argue that as the number of children in a household increases, "quality" of the children decreases, due to the limited resources which can be spent on them. High fertility rates are often associated with a country being underdeveloped as investment in human capital is considered to be a key factor for development Romer et al. (1990); Rebelo (1991). Family planning is also associated with improved maternal health, increase in mothers' years of schooling and access to better job opportunities Miller (2010); Banerjee and Duflo (2012). Last, but not least, is the important effect family planning programs can have on the environment. Many economists, perhaps most sonorously voiced by Sachs (2008) in recent years, have talked about irreversible damages that high population has inflicted upon the earth. For all these reasons, implementing the right population control policy at the right time is of utmost importance, especially in the developing and underdeveloped countries.

Many population control policies were introduced in developing countries in the 1960s (Cleland et al. (2006)) and some are still in place: The PROFAMILIA program in Colombia and the network of rural health houses in Iran provided easy and cheap access to contraceptives (Miller (2010); Salehi-Isfahani et al. (2010)). Iran also began educating families about necessity and methods of family planning through health houses, pre-marital classes and a mandatory family planning course in universities after Iran-Iraq war ended in 1989. India has been paying couples to delay child bearing and have smaller family sizes, among other measures (Connelly (2006)). China's infamous one child policy and Iran's removal of government subsidies for children of fourth and higher parities are examples of legislative/punitive actions taken by governments. Providing greater access to medical facilities (like expansion to health house network in Iran) and promoting delayed marriages in countries like Kenya are other examples of policies employed to slow down population growth (Ikamari (2005)).

There has been a long debate among economists over the effectiveness of population control policies. Demand-side economists see fertility decline mostly a result of the reduction in the desired number of children. More education, increase in the opportunity cost of women, and industrialization are some of the reasons for decrease in the demand for children (See Pritchett (1994); Breierova and Duflo (2004); Lavy and Zablotsky (2015), for example). On the other hand, supply-side economists believe fertility decline is driven by the easier access to/prevalence of family planning techniques (Bongaarts et al. (2012, 1990); Robey et al. (1993)). Miller and Babiarz (2016) give a comprehensive review of micro-level empirical studies on the effectiveness of family planning programs in middle and low-income countries and conclude that: "Although effect sizes are heterogeneous, long-term studies imply that in practice, family planning programs may only explain a modest share of fertility decline in real-world settings (explaining 4-20% of fertility decline among studies finding significant effects). Family planning programs may also have quantitatively modest - but practically meaningful - effects on the socio-economic welfare of individuals and families.".

Among the countries with family planning programs in place to control population growth, Iran is a unique example. It is named as one of the most successful examples (if not the most) of population control. The country's fertility rate dropped from 6.52 in 1981 to 1.87 in 2006 (a 71% drop in 25 years). Its population growth rate also decreased from 3.91% to less than 1.17% in the same period. In different points in time, Iranian government put different population control policies into action. For these reasons, we think it deserves some special attention.

There has been a few attempts to study the effects of these different policies on Iran's fertility rate. Raftery et al. (1995) look at the family planning programs in the Shah's regime (prior to 1979) and find no evidence that the Family Planning Program or Family Protection Act of 1967 resulted in a decline in marital fertility. Salehi-Isfahani et al. (2010) use difference in difference method and the timing of establishment of rural health houses between 1986 and 1996 to estimate the change in average fertility rate between villages with an established health house and those without one. They find that the child-woman ratio declined (at most) 20 percent more in their treatment groups compared to their comparison group. Hashemi and Salehi-Isfahani (2013) try to estimate the impact of the health houses in rural areas on the hazard rate of first to third child. They study three different periods: 1979-1988, in which health houses offered health care services to mothers and children, 1989-1994 in which health houses began offering birth control options, and 1994-2000, the period after parliament passed Population Control Law. They find that health houses decreased the hazard of second and third child after 1989. These results, although substantial, do not explain the sharp decrease in fertility entirely. We believe that apart from establishment of health houses, other factors (possibly other components of Iran's family planning program) are responsible for the country's fertility decline. One of these components is the Population Control Law (hereafter PCL or 1993 PCL) which was passed in May 1993 and came into effect in May 1994.

The Population Control Law (explained in detail in section 3.2.1) cancelled paid maternity leave and some government paid subsidies for children of fourth and higher parities born after May 1994. It also stressed the need for public education and informational campaigns about the benefits of smaller families.

Iran's 1993 Population Control Law (hereafter PCL or 1993 PCL) and withdrawal of government subsidies, in particular, likely influenced the fertility decisions of families who would be potentially affected by it. In this paper, we study the effects of the 1993 Population Control Law on the probability of having a child of fourth or higher order parities. To the best of our knowledge, this is the first paper that looks at this particular question. In order to evaluate the effectiveness of this law on reducing fertility, we employ a difference in difference strategy. We take families with three or more children as treated and families with less than three children as the untreated group. Our results show that this policy had a modest effect of 8% on reducing probability of having one more child for families with three or more children. It had its maximum impact in four years and the effect size gradually decreased after that. These results are in line with Miller's conclusion about the moderate share of family planning programs in fertility decline around the world in general (Miller and Babiarz (2016)).

The rest of this paper is organized as follows: Section 3.2.1 describes the history of family planning programs in Iran, and in particular the 1993 Population Control Law. We talk about the data sets we are using in Section 3.2.2. In section 3.3, we talk about our methodology and empirical strategy in detail. Regression results are explained in section 3.4. Finally, we conclude in section 3.5.

3.2 Institutional Background and Data

3.2.1 History of Family Planning Programs in Iran

After the Islamic Revolution in 1979, government authorities cancelled the existing family planning programs in Iran. International organizations were forced to leave the country and all family planning activities were shut down in the Ministry of Health. The Islamic government proclaimed family planning as a western (and political) concept designed to weaken the country.

In addition, government started to support early age marriage and larger families by providing cheaper housing to larger families and exemption of men with more than three children from compulsory military service. All these, plus the influx of immigrants to Iran from neighboring countries like Afghanistan, resulted in a peak population growth rate of 3.9% in 1981 (Pilehvari (2008)).

Being left to deal with the catastrophic damages to its infrastructure after Iran-Iraq war ended in 1988, and the demands of a rapidly growing population, Iranian Government initiated different projects to promote family planning and smaller family size. The country's health care network started supplying contraception to married couples. In rural areas an existing system of so called "Health Houses" began growing rapidly. These health houses educated families about family planning and provided birth control means to those seeking them.

One of the famous programs starting in 1989 in Iran, was the campaign to promote smaller family size with two simple, yet effective slogans: "Stop! Two children, tops" and "Fewer Children; Better Life". These slogans were painted on the walls, displayed on public transit and printed on milk bottles and grocery packaging. Being short and rhythmical, they were well remembered and frequently recited.

Population Control Law, passed in May 1993 and fully in effect after May 1994, cancelled paid maternity leave, childcare and healthcare subsidies for the children of fourth and higher parities who were born after May 1994. Food subsidies (then given in the form of coupons) were also withdrawn for those children. The law required Ministry of Education to effectively include topics related to population control and mother and child health in the school curriculum. Ministry of Science, Research and Technology and Ministry of Health were asked to introduce "Population and Family Planning" as a mandatory course for all university majors. Ministry of Culture was asked to cooperate with journalists, film makers, and other artists in using different media to encourage smaller family sizes. Finally, Iranian Broadcasting Organization was required to produce different educational programs to (directly or indirectly) educate public about mother and child health.

Iran's 1979 Labor Law allowed three months of paid maternity leave for every child. It also permitted the female workers to take a paid half-an-hour leave per three hours of work ("Child Feeding Time") and required the employers to provide childcare facilities for their female workers. These were all to be withdrawn for the children of fourth and higher parities from May 1994. The employee's share of monthly healthcare premiums (1.65% of monthly base wage for the whole family until then) did not cover children of fourth and higher parities after 1993 PCL was in effect. For each additional child born after May 1994, families had to pay approximately 1.5% of monthly base wage as health insurance premium; so a fourth child would have effectively doubled the health insurance cost of the family.

Lastly, total subsidies paid to consumers, producers, and service providers was 3,686.3 billion Rials in 1994 (amounting to 63,194 Rials per person), 85% of which was in the form of consumption subsidies (Ahmadvand and Eslami (2005)).[2] A significant part of these consumption subsidies were paid in the form of coupons (or rations) and were withdrawn for children of fourth and higher parities after 1994.

3.2.2 Data

Our main data comes from the publicly available 2% random sample of the 2006 Iranian census data.[3] The census used to take place every ten years prior to 2006 and every five years after that. It gathers information on household and individual characteristics including family composition, month and year of birth, marital status, education, employment status, occupation, religion, citizenship, and residency. Summary statistics for the key variables are reported in Table 3.1 for families with one or two children and families with three or four children (comparison and treatment groups in our difference in difference strategy).

[2]For comparison, note that minimum monthly wage was 116,820 Rials in the same year.

[3]Publicly available at www.amar.org.ir.

Table 3.1: Summary Statistics - 2006 Iranian census

	Families with 1 or 2 children	**Families with 3 or 4 children**
% Female Children:	46.01	46.65
Mother's Age:	35.76	41.21
Mother's Education:		
Illiterate	15.55	26.41
Primary	24.23	34.13
Secondary	44.94	29.11
Post Secondary	12.94	7.38
Unofficial Education	2.34	2.98
Father's Education:		
Illiterate	21.34	38.80
Primary	26.44	36.37
Secondary	42.09	20.84
Post Secondary	8.52	2.32
Unofficial Education	1.61	1.67
% Employed or have income:		
Mother:	12.69	9.41
Father:	92.53	92.01

Using census data, we construct birth records which in turn are used to define treatment status and outcome variable. Our treatment group consists of married couples with three or more children and the comparison group consists of married couples with one or two children. We limit our sample to families with 15-50 year old mothers who are present in the household.

Table 3.1 suggests that women with more children are on average older, probably because fertility is not completed for younger women in our sample. Also, mothers with fewer children are more likely to have higher education and to be employed. This may reflect the higher opportunity cost of having children for more educated and working women.

One important limitation of using birth records constructed from census data for our purposes is that it will not allow us to control for any further covariates other than the very basic policy variables we need plus the parents' age.

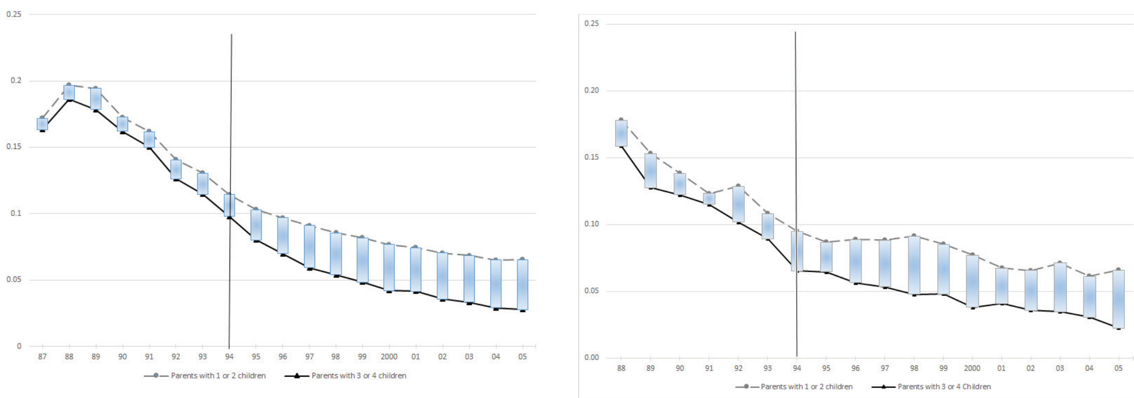
Our empirical strategy is taking care of any time-variant unobserved factors affecting our comparison and treatment groups in the same way (like access to contraceptives through health houses) by using year fixed effects. However, there may be other factors changing systematically differently for our comparison and treatment groups over time.

Mothers with one or two children are on average younger with fewer household responsibilities and more free time. As a result, they are more likely to participate in the labor force or to continue their education, when having the opportunity to do so. One such opportunity arose with the rapid expansion of the number of universities in Iran. Mothers with fewer children were more likely to attend a university. If this increase in education further affects the outcome variable, we may over or underestimate the true effect of the Population Control Policy.

To address this issue, we use a secondary data source that allows us to control for mothers' education and employment status over the years. This data set is the annual Household Expenditure and Income Surveys (HEIS: 1988-2005) conducted by the Statistical Center of Iran. The survey gathers information on demographic characteristics for each member of the surveyed family, such as age, sex, education, employment status, marital status, and the relationship to the head of the household. It also collects detailed information on household income and expenditure. The HEIS is nationally representative and the coverage rate has increased from more than 11000 households in 1989 to more than 38000 households in 2010. Once again, we limit our sample to married couples where the mother is present in the family and is in the 15-50 age range.

The most important shortcoming of the HEIS, for our purpose, is that it does not report the year and month of birth. As the survey is conducted throughout the year, some of our important variables, including our outcome variable (having given birth in a particular year), are subject to measurement error. Consider the following example: The 1993 cycle of HEIS begins in March 1993 (March marks the beginning of the new year in Iran) and ends in April 1994. A family who gave birth to their third child in April 1992 will have a

Figure 3.1: Conditional Probability of giving birth to another child



(a) (b)

Source: Authors' calculation based on 2% sample of 2006 Iranian Census (a) and HEIS 1988-2005 (b), publicly available at www.amar.org.ir
Notes: Horizontal axis shows the years. Vertical axis shows the average percentage of mothers who have given birth in each year.

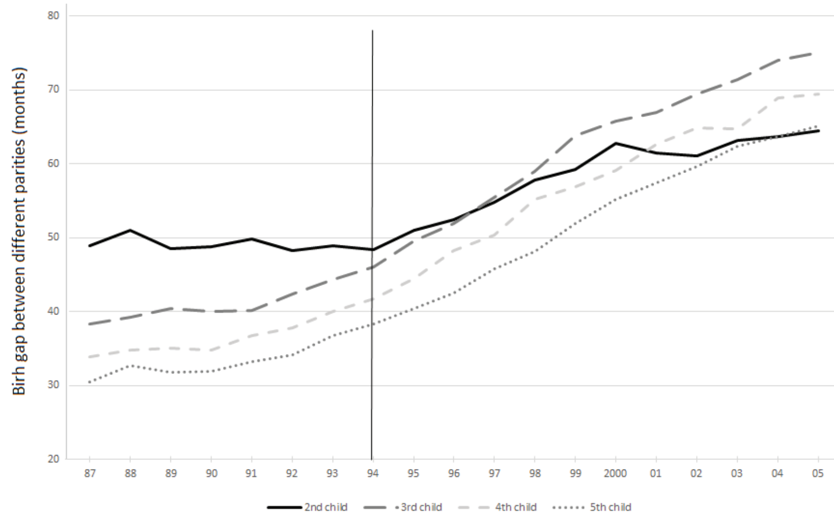
record of new born (age=0), if surveyed in March 1993. Another family with their third child born in April 1994 and surveyed in the same month will also have a record of a child with age zero in 1993 HEIS cycle. Both of these families will be considered as treated in our analysis, while the latter actually should be in our comparison group, as they had two children in May 1993. The outcome variable, whether the family had a newborn child in a given year, will be equal to one for both of these families, whereas neither family actually gave birth to a new child in 1993.

As the sample census data contains information on the month and year of birth, it will dramatically reduce the measurement error of the outcome variable. For this reason, we use census as our main data source, despite its shortcomings.

Panels (a) and (b) in Figure 3.1, illustrate the percentage of families who gave birth to another child over the years for our comparison and treatment groups. Panel (a) is using the birth records constructed from 2006 census data and panel (b) is using HEIS data. We observe similar trends in both graphs. On average, the probability of having another child decreases as time goes by for both our treatment and comparison groups, and irrespective of which data set is used. However, one can easily see that until 1994, when the PCL came into effect, the difference between the two groups of is small and remains relatively constant. After 1994, this gap becomes wider and remains so over the time. In other words, families who are affected by 1993 Population Control Law become less likely to have another child.

In our opinion, PCL could have affected fertility decisions of the families through two possible channels: It might have reduced the desired number of children and/or it might have increased the gap between different parities. We are not able to separate the effects

Figure 3.2: Birth spacing for different parities



Source: Authors' calculation based on publicly available 2% sample of 2006 Iranian Census at www.amar.org.ir.
Notes: The horizontal axis shows the years and the vertical axis shows the average waiting time for each parity in months.

of these two mechanisms in our model. However, we believe the policy has worked through both channels. Figure 3.2 illustrates the average birth spacing between different parities over the years. The solid line in Figure 3.2 shows the average wait time between the first and the second child in months.

These patterns are consistent with the results of Hashemi and Salehi-Isfahani (2013). After 1989, with the end Iran-Iraq war and the reversal of pro-natalist policies of Iranian government, waiting time for the 3rd and higher order births gradually increased over time. However, it appears that the average wait time for second child was not affected by those policies and remained just above 48 months up until 1994. It is only after this year that the average wait time for the second child starts to increase and within 6 years, it reaches 60 months. This may well be the result of the 1993 Population Control Law and the campaign to educate public about family planning.

3.3 Methodology

We are interested in the effect of the 1993 Population Control Law on the probability of having children of fourth or higher parities. As this policy penalizes families with three or more children who gave birth after May 1994, the natural comparison group would be families who had less than three children. Our research design is based on the following difference in difference framework:

$$Y_{it} = \alpha + \beta D_{it} + \mu_t + \sigma PCL_{it} + \theta Age_{it} + \epsilon_{it} \tag{3.1}$$

where Y_{it}, our outcome variable, is an indicator of whether or not individual i has given birth to a new child in year t, μ_t denotes a set of year fixed effects and Age_{it} controls for mother i's age in year t. The treatment status, D_{it} is an indicator for our treatment group (families with 3 or more children before the implementation of the PCL in 1994), and PCL_{it} is the interaction between D_{it} and an indicator for years after 1994.

Defining D_{it} and PCL_{it} based on the actual treatment status in year t will violate the random assignment of treatment that assumes treatment status should not change with the outcome variable. So, to capture the causal effect of the treatment, we base our analysis on the initial assignment of individuals to treatment and comparison groups and estimate the intention to treat (ITT) effect.

As mentioned earlier, to see how sensitive our estimates are to the inclusion of socioeconomic status, namely education and employment, we are using repeated cross-section data of the Household Expenditure and Income Surveys (HIES: 1989-2005). Since these are repeated cross-section surveys, unlike with the birth records constructed from 2006 Iranian Census, we are able to unbiasedly estimate the average treatment on treated (ATT) effects.

To further extend our analysis, we are using equation (3.2) to study the evolution of the treatment effect over time.

$$y_{it} = \alpha + \beta D_{it} + \mu_t + \sum_{\tau=-m}^{q} \sigma_\tau PCL_{\tau,it} + \theta Age_{it} + \epsilon_{it} \tag{3.2}$$

where y_{it}, D_{it}, μ_t and Age_{it} are defined as in equation (3.1) and $PCL_{\tau,it}$ is composed of a set of dummy variables that take value one only if individual i is in the treatment group, and year t is $|\tau|$ years before ($\tau < 0$) or after ($\tau > 0$) the policy came into effect. By including q lags of the treatment effect into the model, we are able to see how the treatment effect evolves over time. Moreover, inclusion of m leads of the treatment effect into the model allows us to test whether the parallel trend assumption is satisfied. We are expecting to see $\sigma_\tau = 0, \forall \tau < 0$.

We report the results for a variety of treatment and comparison groups, including families with three versus families with two children, and families with three to five children versus families with one or two children.

3.4 Results

Our main results on the effects of 1993 Population Control Law are reported in Table 3.2. The treatment group consists of families with three or four children and the comparison group consists of families with one or two children. All regressions include year fixed effects and standard errors are clustered at household level.

The second column of Table 3.2 shows the results of our main specification. The estimated effect of Population Control Law on probability of having one more child is −0.66 in the base line of 7.9, a difference of more than 8%. This effect is very precisely estimated (significant at 0.1% level). Comparison of specifications (1) and (2) shows that our results are robust to the exclusion of mother's age from our model. The negative coefficient of age can be easily explained by observing two facts: First, chances of getting pregnant decline sharply with mother's age, and second, there is a higher probability for older women to have already reached their desired number of children in our sample.

Table 3.2: Effect of Population Control Law on probability of giving birth (2006 census data)

	(1)	(2)	(3)	(4)
	Total		Urban	Rural
	Comparison: Families with 1 or 2 children Treated: Families with 3 or 4 children			
PCL	−0·661***	−0·665***	−0·270*	−1·299***
	(0·102)	(0·102)	(0·124)	(0·171)
Age		−0·143***	−0·137***	−0·157***
		(0·002)	(0·002)	(0·003)
Mean Dependent Variable	7·914	7·914	7·138	9·883
R-square	0·04	0·04	0·04	0·05
Observations	2666613	2666613	1593666	1072947

Notes: Dependent variable takes the value of 100 if a family gave birth to another child in a given year and zero otherwise. All regressions include year effects and standard errors are clustered at family level.
(* = significant at 5%, ** = 1%, *** = 0.1%)

Columns (3) and (4) in Table 3.2 show the results for urban and rural subsamples. The policy effect is larger in the rural areas (−1.299) compared to the urban areas (−0.270). This can be attributed to lower desired fertility in urban areas. As an extreme example, if all families in urban areas desire to have three children, the 1993 PCL would have absolutely no effect. Another reason for the gap between rural and urban areas may be the higher sensitivity of rural families to withdrawal of subsidies (in particular, consumption subsidies).

Table 3.3 presents the results of our main specification for various treatment and comparison groups. The top panel in Table 3.3 uses families with three children as treated and families with two children as comparison. The middle panel compares families with one or two children with those with three, four or five children. Finally, the bottom panel compares

Table 3.3: Effect of Population Control Law on probability of giving birth (2006 census data) - Robustness checks

	(1)	(2)	(3)	(4)
	Total		Urban	Rural
	Comparison: Families with 2 children Treated: Families with 3 children			
PCL	$-0{\cdot}974^{***}$	$-0{\cdot}976^{***}$	$-0{\cdot}804^{***}$	$-1{\cdot}032^{***}$
	(0·130)	(0·130)	(0·155)	(0·221)
Mean Dependent Variable	6·994	6·994	6·036	9·458
R-square	0·04	0·04	0·04	0·05
Observations	1366481	1366481	823802	542679
	Comparison: Families with 1 or2 children Treated: Families with 3 to 5 children			
PCL	$-0{\cdot}725^{***}$	$-0{\cdot}724^{***}$	$-0{\cdot}343^{**}$	$-1{\cdot}300^{***}$
	(0·099)	(0·098)	(0·120)	(0·163)
Mean Dependent Variable	7·851	7·851	7·080	9·777
R-square	0·04	0·04	0·04	0·05
Observations	2769502	2769502	1648775	1120727
	Comparison: Families with 1 or 2 children Treated: Families with 3 to 6 children			
PCL	$-0{\cdot}750^{***}$	$-0{\cdot}745^{***}$	$-0{\cdot}366^{**}$	$-1{\cdot}297^{***}$
	(0·098)	(0·097)	(0·119)	(0·161)
Mean Dependent Variable	7·825	7·825	7·059	9·724
R-square	0·04	0·04	0·04	0·05
Observations	2806288	2806288	1667449	1138839
Age	No	Yes	Yes	Yes

Notes: Dependent variable takes the value of 100 if a family gave birth to another child in a given year and zero otherwise. All regressions include year effects and standard errors are clustered at family level.
(* = significant at 5%, ** = 1%, *** = 0.1%)

families with less than three children to those with three to six children. The effect sizes are very similar across all versions, ranging from 8% to 13%, and are all statistically significant at 0.1%.

Table 3.4 shows the results using data from Iranian Household Expenditure and Income Surveys (1988-2005). Columns (1) and (2) report the results for our baseline model without any controls and with control for mother's age, respectively. Although including age dramatically reduces the estimated effect of the policy (from 16.9% to 5.6%), inclusion of mother's level of education and employment status do not seem to cause any further change. Employed mothers and those with higher educations exhibit lower probabilities of having one more child, as expected.

The results for various comparison and treatment groups using HEIS (1988-2005) are presented in Table 3.5. We do not see any significant effects at conventional significance levels for families with two children vs. families with three children. However, for other specifications of comparison and treatment groups, the results are precisely estimated and show the expected sign and magnitude.

Without controls for education and employment status, the average treatment on treated effects vary between 18% and 36%. When we further add these two variables, these effects become closer to what we observe with 2006 census data. One must be cautious when comparing the two coefficients, however, as one estimates the average treatment on treated effect and the other estimates the intention to treat effect.

Tables 3.4 and 3.5 show that although controlling for age, substantially changes the estimate of the parameter of interest, the coefficients are robust to inclusion of education and employment status. This reassures us that there was nothing else going on around the time of the policy that affected our comparison and treatment groups systematically differently.

The estimated policy effect in Tables 3.2 to 3.5 are in fact the average of policy effects over all post-policy periods. To get a sense of dynamics of the effects over time, we estimate equation (3.2). Results are presented in Table 3.6. Our identifying assumption is that in the absence of the treatment, both comparison and treatment groups follow a similar trend. This specification also allows us to test the parallel trend assumption.

All four columns in Table 3.6 show a similar pattern. The estimated coefficients for years leading to adoption date of PCL are mostly small and insignificant. This suggests that our parallel trend assumption holds. For years after the policy, the coefficients are larger and highly significant.

Panel (a) in Figure 3.3 visualizes the results presented in Table 3.6, depicting σ_τs from equation (3.2). We mark 1993, the year the policy came into effect, with a vertical dashed line. We normalize the effects such that they are equal to zero in the year of adoption ($\tau = 0$). The policy has its greatest impact four years after its adoption and the effect

Table 3.4: Effect of Population Control Law on probability of giving birth (Household Expenditure and Income Surveys, 1999-2005)

	(1)	(2)	(3)
	Comparison: Families with 1 or 2 children Treated: Families with 3 or 4 children		
PCL	$-1{\cdot}342^{***}$	$-0{\cdot}449$	$-0{\cdot}403$
	(0·250)	(0·244)	(0·245)
Age		$-0{\cdot}410^{***}$	$-0{\cdot}481^{***}$
		(0·004)	(0·005)
Education:			
Primary			$-2{\cdot}538^{***}$
			(0·158)
Secondary			$-5{\cdot}596^{***}$
			(0·170)
University			$-6{\cdot}038^{***}$
			(0·245)
Unofficial Education			$-0{\cdot}766^{*}$
			(0·303)
Employed			$-0{\cdot}780^{*}$
			(0·303)
Mean Dependent Variable	7·929	7·929	7·872
R-square	0·02	0·07	0·08
Observations	213008	213008	211280

Notes: Dependent variable takes the value of 100 if a family gave birth to another child in a given year and zero otherwise. All regressions include year effects.
(* = significant at 5%, ** = 1%, *** = 0.1%)

Table 3.5: Effect of Population Control Law on probability of giving birth (Household Expenditure and Income Surveys, 1999-2005) - Robustness checks

	(1)	(2)	(3)
	Comparison: Families with 2 children Treated: Families with 3 children		
PCL	0·114	0·595	0·590
	(0·322)	(0·316)	(0·316)
Mean Dependent Variable	7·168	7·168	7·112
R-square	0·03	0·06	0·07
Observations	117509	117509	116613
	Comparison: Families with 1 or 2 children Treated: Families with 3 to 5 children		
PCL	−1·507***	−0·652**	−0·643**
	(0·232)	(0·227)	(0·228)
Mean Dependent Variable	7·816	7·816	7·756
R-square	0·03	0·07	0·07
Observations	248096	248096	245982
	Comparison: Families with 0 to 2 children Treated: Families with 3 to 6 children		
PCL	−3·070***	−2·193***	−2·122***
	(0·211)	(0·205)	(0·206)
Mean Dependent Variable	8·323	8·323	8·276
R-square	0·02	0·08	0·08
Observations	308906	308906	305998
Age	No	Yes	Yes
Education	No	No	Yes
Employment Status	No	No	Yes

Notes: Dependent variable takes the value of 100 if a family gave birth to another child in a given year and zero otherwise. All regressions include year effects.
(* = significant at 5%, ** = 1%, *** = 0.1%)

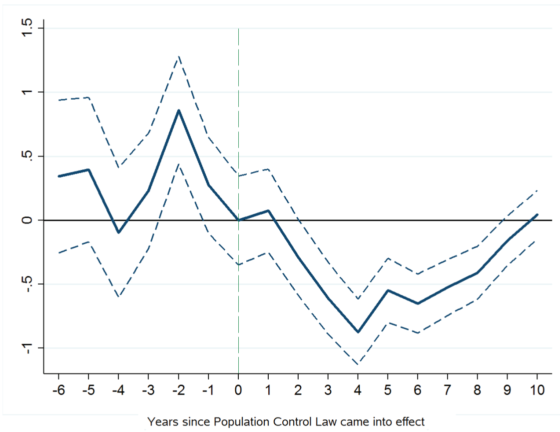
Table 3.6: Effect of Population Control Law on probability of giving birth over time (2006 census data)

	(1)	(2)	(3)	(4)
	Total		Urban	Rural
	Comparison: Families with 1 or 2 children Treated: Families with 3 or 4 children			
PCL_{-6}	−0·032	−0·010	−0·689	1·537*
	(0·363)	(0·363)	(0·449)	(0·601)
PCL_{-5}	0·025	0·042	−0·392	0·908
	(0·343)	(0·343)	(0·424)	(0·568)
PCL_{-4}	−0·429	−0·450	−0·450	−0·695
	(0·309)	(0·309)	(0·384)	(0·505)
PCL_{-3}	−0·092	−0·124	−0·501	0·275
	(0·274)	(0·274)	(0·335)	(0·469)
PCL_{-2}	0·544*	0·506*	0·284	0·399
	(0·256)	(0·256)	(0·313)	(0·438)
PCL_{-1}	−0·044	−0·079	−0·682*	0·570
	(0·228)	(0·227)	(0·273)	(0·404)
PCL_{0}	−0·327	−0·354	−0·924***	0·153
	(0·211)	(0·211)	(0·254)	(0·377)
PCL_{+1}	−0·253	−0·279	−0·762**	0·171
	(0·198)	(0·198)	(0·237)	(0·355)
PCL_{+2}	−0·619***	−0·644***	−1·167***	0·019
	(0·181)	(0·181)	(0·215)	(0·330)
PCL_{+3}	−0·939***	−0·962***	−1·223***	−0·753*
	(0·171)	(0·171)	(0·205)	(0·307)
PCL_{+4}	−1·207***	−1·229***	−1·259***	−1·456***
	(0·158)	(0·158)	(0·190)	(0·282)
PCL_{+5}	−0·881***	−0·902***	−0·971***	−0·943***
	(0·152)	(0·152)	(0·185)	(0·268)
PCL_{+6}	−0·985***	−1·004***	−0·971***	−1·239***
	(0·140)	(0·140)	(0·168)	(0·252)
Age	No	Yes	Yes	Yes
Mean Dependent Variable	7·914	7·914	7·138	9·883
R-squared	0.04	0.04	0.04	0.05
Observations	2666613	2666613	1593666	1072947

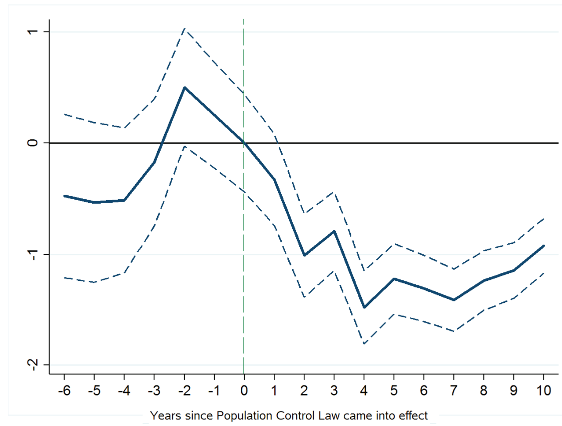
Notes: Dependent variable takes the value of 100 if a family gave birth to another child in a given year and zero otherwise. All regressions include year effects and standard errors are clustered at family level.
(* = significant at 5%, ** = 1%, *** = 0.1%)

starts to become smaller as time goes by. The remaining panels in Figure 3.3 show the results for various comparison and treatment groups.

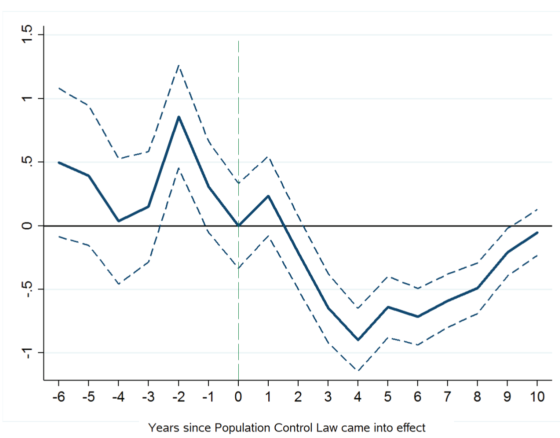
Figure 3.3: Effect of Population Control Law over time



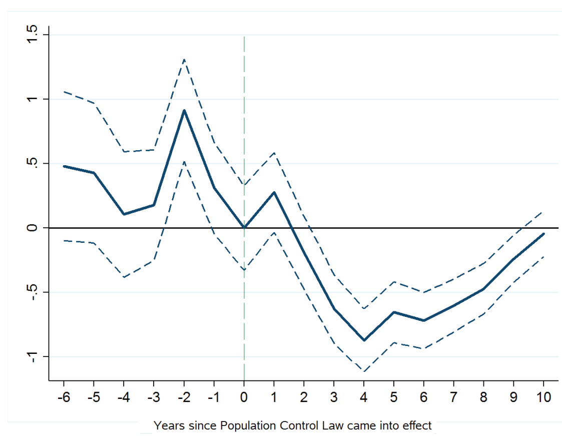
(a) Parents with 1-2 children vs. 3-4 children



(b) Parents with 2 children vs. 3 children



(c) Parents with 1-2 children vs. 3-5 children



(d) Parents with 1-2 children vs. 3-6 children

Notes: The figures provide graphical analysis of the effect of the Population Control Law over time. The year of the policy's adoption (1993) is set equal to zero and the effects are normalized so that they are equal to zero in the adoption year. The blue dashed lines show the 90 percent confidence intervals for the estimated coefficients.

It is important to notice that the health house network continued to expand in rural areas even after the 1993 PCL. The rural families tend to be larger (and mostly included in our treatment group). If the health houses reduced the desired number of children, the decline in probability of having another child in the rural areas might be wrongfully attributed to the policy and lead to overestimation of its effects. Consequently, the estimated coefficients must be interpreted with caution.

3.5 Concluding Remarks

In this paper, we studied a population control policy, implemented in Iran in 1993. We find that this policy had a small to moderate effect on reducing the probability of having one more child for Iranian families. Although we are not able to identify the exact mechanism through which the policy acted (leaving the door open for further research), we have reasons to believe different channels resulted in lower population growth rates. Either the policy had changed the demand for children (reducing total cohort fertility), or it had resulted in families spacing out their children. Even in the latter case, the fact that the female fertility declines sharply after a certain age would mean fewer births over a woman's lifetime.

We would also like to draw readers' attention to the fact that effects of the policy are not constant over time. The policy has its biggest impact in the years immediately following its implementation date. However as time passes, these effects become less pronounced. This indicates the importance of the selected time span for the future policy researchers who are trying to evaluate/introduce such policies.

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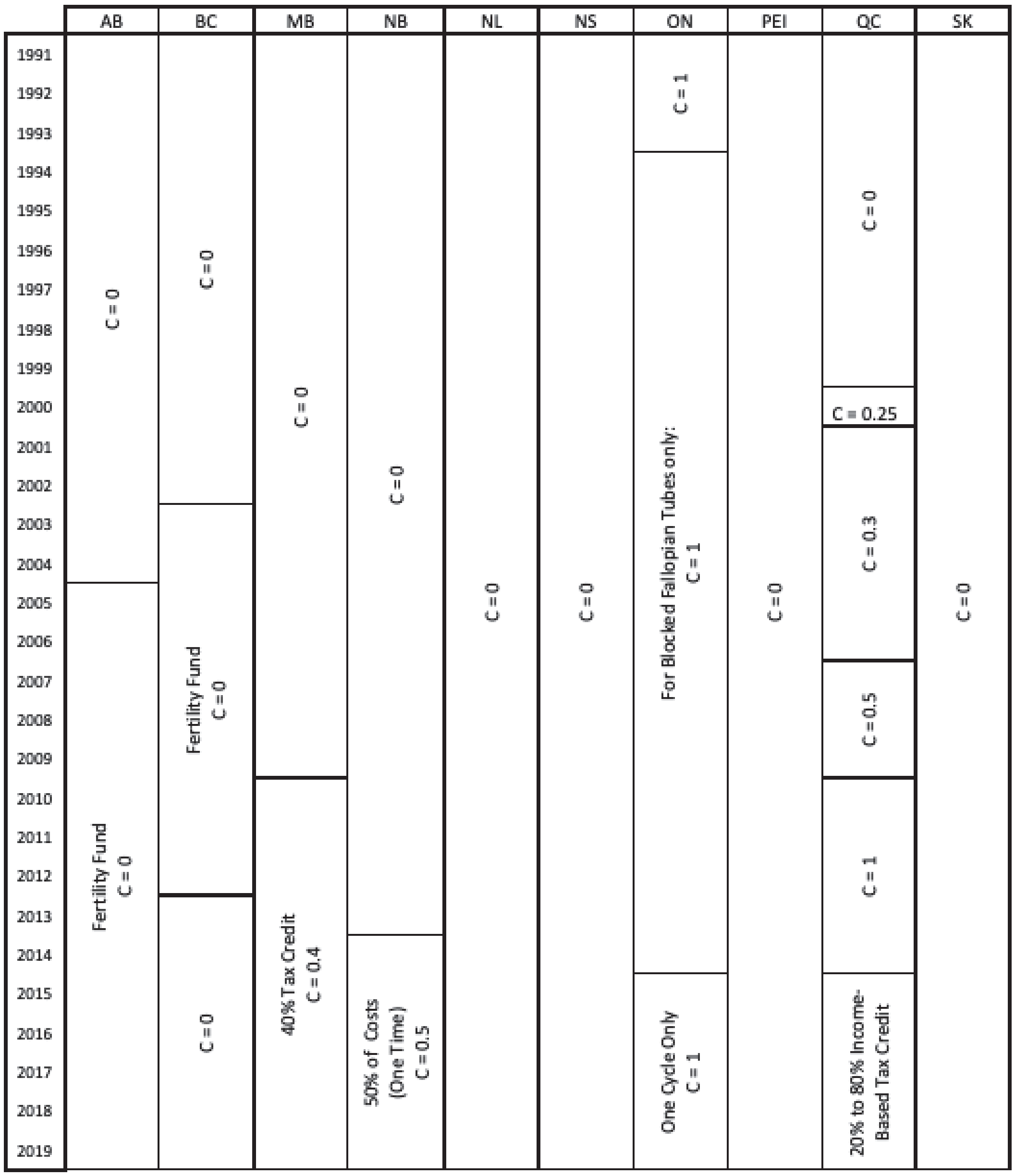
Appendix A

Continuous Coverage Variable

The following Figure summarizes the details for the IVF coverage plans under public health insurance in different Canadian provinces from 1991–2019. Variable C shows the percentage of IVF costs covered by public health plans and is what I have used for the values of my continuous policy variable in Section 2.3.

Figure A.1: Percentage of IVF costs publicly covered by provinces



Appendix B

Estimates Weighted by Populations

This appendix reports the result of my main regression with both binary and continuous policy variables, weighted by 2010 population for each province. Although the selection of the year is arbitrary, the results are robust to the choice of a different year. For the continuous model, I have used 50% as the level of coverage for Quebec between 2015 and 2019 to be consistent with Table 2.4.

Table B.1: Effect of IVF coverage by public health plans on multiple births - binary policy variable (AB and BC excluded)

	(1)	(2)	(3)	(4)
VARIABLES	1991-2019		2000-2019	
IVF Coverage (C_{it})	-200.5**	-152.7*	42.46	-0.620
	(59.06)	(68.36)	(141.1)	(150.7)
Unemployment_Rate		10.13		34.91*
		(16.09)		(14.78)
Inflation		3.827		-97.24***
		(8.820)		(26.21)
Income		-0.0150		0.0103
		(0.00989)		(0.0104)
Observations	232	232	160	160
R-squared	0.909	0.912	0.661	0.688

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Dependent variable is multiple births per 100,000 live births. Policy variable is whether a province had any policy in place to partially or totally cover IVF expenses. All regressions include province and year effects.

Table B.2: Effect of IVF coverage by public health plans on multiple births - binary policy variable (AB and BC included)

VARIABLES	(1)	(2)	(3)	(4)
	1991-2019		2000-2019	
IVF Coverage (C_{it})	-123.1*	-96.10	-50.15	-46.07
	(62.89)	(54.86)	(47.00)	(40.65)
Unemployment Rate		21.61		11.54
		(15.22)		(16.82)
Inflation		9.383		-29.42
		(14.23)		(18.50)
Income		-0.00651		-0.00897
		(0.0101)		(0.0108)
Observations	290	290	200	200
R-squared	0.912	0.915	0.646	0.658

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Dependent variable is multiple births per 100,000 live births. Policy variable is whether a province had any policy in place to partially or totally cover IVF expenses. All regressions include province and year effects.

Table B.3: Effect of IVF coverage by public health plans on multiple births - continuous policy variable (AB and BC excluded)

VARIABLES	(1)	(2)	(3)	(4)
	1991-2019		2000-2019	
IVF Coverage (C_{it})	-327.6***	-291.1**	-175.7	-177.0
	(75.14)	(116.2)	(101.1)	(135.4)
Unemployment_Rate		-8.391		24.72
		(24.19)		(24.19)
Inflation		0.751		-101.5**
		(8.625)		(31.58)
Income		-0.0179*		0.0128
		(0.00914)		(0.0127)
Observations	232	232	160	160
R-squared	0.912	0.914	0.672	0.699

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Dependent variable is multiple births per 100,000 live births. Policy variable is the proportion of IVF expenses that are covered by public health plans. All regressions include province and year effects. Alberta and BC are excluded from the data.

Appendix C

Binary Policy Variable, Including AB and BC

In this appendix I present the results of the regressions with binary policy variable, when the data includes provinces of Alberta and British Columbia. $C_{it} = 1$ for BC from 2003 to 2012 and for Alberta since 2005, when non-governmental fertility funds were active in these provinces.

Table C.1: Effect of IVF coverage by public health plans on multiple births - binary policy variable (AB and BC included)

	(1)	(2)	(3)	(4)
VARIABLES	1991-2019		2000-2019	
IVF Coverage (C_{it})	-65.53	-48.32	-15.22	-5.895
	(77.43)	(75.41)	(79.70)	(69.73)
Unemployment Rate		-25.33		-20.78
		(22.28)		(23.53)
Inflation		12.65		-59.70*
		(20.08)		(30.97)
Income		-0.00768		0.00604
		(0.0107)		(0.0136)
Observations	290	290	200	200
R-squared	0.737	0.740	0.372	0.386

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Dependent variable is multiple births per 100,000 live births. Policy variable is whether a province had any policy in place to partially or totally cover IVF expenses. All regressions include province and year effects.

Appendix D

Different Quebec Coverage Levels

This appendix reports the result of my main regression with continuous policy variable for different coverage levels assigned to Quebec from 2015 to 2019. As the tax credit for IVF treatment can vary between 20% and 80%, the following table D.1 shows the results for 20%, 40%, 60%, and 80% tax credit. Results for a tax credit of 50% are presented in the main body of the paper.

Table D.1: Effect of IVF coverage by public health plans on multiple births - Different Coverage Rates for Quebec after 2015

	(1)	(2)	(3)	(4)
VARIABLES	20%	40%	60%	80%
IVF Coverage (C_{it})	20.29	9.914	-4.286	-19.25
	(132.8)	(153.6)	(168.0)	(169.1)
Unemployment_Rate	-7.131	-6.641	-6.389	-6.511
	(36.93)	(36.74)	(36.90)	(37.48)
Inflation	-75.16*	-74.92*	-74.57*	-74.18*
	(37.70)	(37.85)	(38.01)	(38.14)
Income	0.0206	0.0207	0.0206	0.0203
	(0.0141)	(0.0142)	(0.0143)	(0.0143)
Observations	160	160	160	160
R-squared	0.389	0.389	0.389	0.389

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Dependent variable is multiple births per 100,000 live births. Policy variable is the proportion of IVF expenses that are covered by public health plans. All regressions include province and year effects (2000-2019).

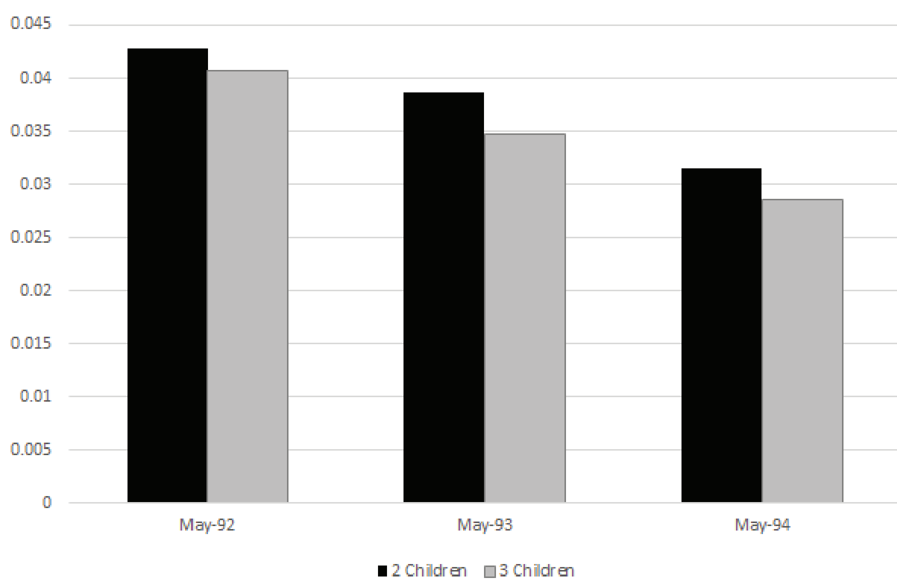
Although the coefficients are insignificant and very small, they depict a clear picture. A higher tax credit is associated with a steeper decline in multiple birth rates. One obvious reason may be the lack of pressure to transfer multiple embryos at once due to financial pressures.

Appendix E

Heterogeneous effects

As there is a one year gap between the passage of the PCL and its implementation, one may expect an increase in the number of higher order births (4 and more) in this "Transition Period". Parents with more than three children as of May 1993, who desired even a greater number of children would have seen the Transition Period as the time to increase their family size without suffering the penalties 1993 PCL would have imposed on them otherwise. Figure E.1, shows the probabilities of having another child for people with two and three children exactly one year before passage of PCL, in May 1993 when the law was passed in parliament and in May 1994, exactly one year after. Our regression results also do not show a significant difference in the gap between the two probabilities during this period.

Figure E.1: Heterogeneous effects of 1993 PCL in transition period



Source: Authors' calculation based on publicly available 2% sample of 2006 Iranian Census at www.amar.org.ir.
Notes: Average percentage of families with two or three children in May 1992, May 1993 and May 1994 who gave birth in the following nine to twelve months.