Do investment tax credits foster innovation? The Alberta Investor Tax Credit and patent applications

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The idea that positive knowledge spillover from research efforts disincentivizes its private sector investment has led to widespread support for fiscal incentives to promote innovation. Although the literature on research and development (R&D) tax credits is extensive, alternative innovation policy has been understudied. Using a two-way fixed effects difference-in-differences estimator, I investigate the impact of the Alberta Investor Tax Credit (AITC), which offered a tax credit for investments in innovative businesses. Estimates show that after the AITC implementation, patent applications from Albertan parties did not increase significantly, suggesting that the intervention was unsuccessful in fostering innovation.

1 Introduction

Creative destruction, the process through which the invention of new products, methods or processes lead to the obsolescence of old ones, was seen by Joseph Schumpeter as the "essential fact of capitalism" (Caballero 2010, p.24), and widely incorporated in economic theory as a determinant of long-run economic growth (Aghion and Howitt 1992; Artz et al. 2010; Jones 1995). For a society to engage in creative destruction, it must invest in its innovative capacity, and researchers have recognized that such investment resembles a public good, which results in free-riding and a suboptimal level of private innovation (Bloom, Van Reenen, and Williams 2019). A large body of work has emerged to study fiscal incentives for innovation, notably on research and expenditure (R&D) tax credits, yet alternative fiscal policy has received little attention. In this paper, I investigate a fiscal policy aimed to increase investment in innovative firms, the Alberta Investment Tax Credit (AITC), and its effect on patent applications.

The extensive literature on the effects of R&D tax credits has mostly found that these programs positively impact R&D expenditure[1] and it has been observed that countries with higher R&D to GDP ratios grow faster (Jones 2016). R&D tax credits typically involve subsidizing R&D by lowering the firm's tax bill, hence increasing incentives for such expenses. However, observed stagnation in productivity growth in developed economies despite the growth in R&D expenditure has questioned the validity of the R&D and innovation relationship (Griliches 1988). Particularly, despite Canada being one of the most generous tax jurisdictions for R&D, the country has not seen a significant R&D intensity ratio (McKenzie 2006). This apparent paradox underscores the importance of understanding how alternative policy, such as tax credits for investments in inventive firms, can affect innovation outcomes.

In January 2017, the Government of Alberta passed the *Investing in a Diversified Alberta Economy Act*, which introduced the Alberta Investor Tax Credit (AITC), a tax credit for investors who financed Albertan firms undertaking research, development and commercialization of new technology. The AITC aimed to provide easier access to financing for innovative firms. I map patent applications to provinces with a novel administrative dataset from the Canadian Intellectual Property Office (CIPO), using the reported locations of parties from

1. See Becker (2015), Hall, Mairesse, and Mohnen (2010) and Hall and Van Reenen (2000) for a review.

patent applications. Through this mapping, I estimate the impact of the AITC on patent applications using a two-way fixed effects difference-in-differences design. My results show that after the AITC was passed, Albertan parties did not significantly increase their patent applications relative to other provinces that did not pass similar legislation. I validate my results using an event study design, showing that most pre-intervention periods show no statistically significant differences between treatment and control groups.

I perform two robustness checks to ensure the validity of the null result. I replicate the analyses using parties in applications as the innovation outcome, finding that there is no significant deviation from the null result. This ensured the result was not driven by the mapping of applications to provinces. I also reestimated models using higher frequency data, finding that the null result persisted. Moreover, the relatively small size of the standard errors in my estimates shows that it is unlikely that the null effect is due to imprecision.

Focusing on patent applications is a useful way to measure innovation when R&D is not observed by the researcher. Patent statistics have been extensively used to measure innovation, as they proxy the outputs of the inventive process (Nordhaus 1969; Pavitt 1985; Trajtenberg 1990; Artz et al. 2010). Patents have been used to estimate the knowledge spillover generated by the innovation process, specifically using patent citations in patent applications (Trajtenberg 1990; Jaffe, Trajtenberg, and Henderson 1993). While using patent data has been shown to have limitations (Lanjouw, Pakes, and Putnam 1998), others have shown that patents move together with other innovation products (Lanjouw and Schankerman 2004).

My findings make three contributions to the literature. First, I provide the first evidence on how investment tax credits affect innovation outcomes. The AITC is a unique policy in that it provides easier access to financing for innovative firms, rather than subsidizing R&D expenditure. The investment tax literature has typically focused on macroeconomic impacts and firm outcomes, mostly finding positive effects (Pereira 1994; Lyon 1989; Slattery and Zidar 2020). This owes to the fact that investment tax credits are typically used to stimulate investment in capital goods, which has a fundamentally different purpose to the traditional R&D tax credits. However, modern programs such as the AITC have received significant attention from the public (Alberta Chamber of Commerce 2023; Zabjeck 2016), which may lead to the increased use of similar policies by governments. The literature should incorporate nontraditional fiscal incentives to understand how they affect innovation outcomes.

Second, to my knowledge, no other paper evaluates any type of fiscal incentive on intellectual property outcomes. The literature has mainly focused on how R&D tax credits affect R&D expenditure. Focusing on such outcome as the main measure for innovation has been criticized for not capturing innovation outside the R&D process (Xie, Wang, and Jiao 2019). Using patent applications as the explained variable allows me to capture innovation not necessarily produced through a research and development process. Further, recent evidence has shown that tax credits may induce the relabeling of non-innovative business expenditure as R&D by firms to leverage tax savings (Chen et al. 2021). The incompatibility between the slowdown in productivity growth and the positive effects of R&D tax credits may be explained by this phenomenon.

Third, I extend the literature on Canadian fiscal policy, which has centered on the Scientific Research and Experimental Development (SR&ED) programs. The SR&ED programs have motivated a large literature, most of which has found positive effects of the programs on R&D expenditure (Agrawal, Rosell, and Simcoe 2020; Czarnitzki, Hanel, and Rosa 2011; Bérubé and Mohnen 2009; Mansfield and Switzer 1985b; Bernstein 1986). This literature has relied on firm-level outcomes and quasiexperimental designs, exploiting changes in program eligibility or provincial policy changes to estimate treatment effects. However, these findings are also unable to reconcile the stagnation in R&D intensity in Canada with the positive effects of the SR&ED programs. Providing new evidence on how fiscal incentives affect innovation outcomes in Canada is crucial to understanding the Canadian innovation landscape.

The rest of the paper proceeds as follows. Section 2 provides an overview of the AITC and the Canadian institutional context. Section 3 describes the empirical strategy. Section 4 presents the paper's results. Section 5 concludes.

2 Institutional context

In this section, I review the details of the Alberta Investor Tax Credit (AITC) program. Further, I review the intellectual property environment in Canada, which will be directly relevant to the definition of my explained variable. Finally, I review the existing incentives for research and development (R&D) expenditures of Canadian federal and provincial governments, which are relevant to the identification strategy of the AITC's effect on innovation.

2.1 The Alberta Investor Tax Credit

The AITC was a three-year tax credit program initiated by the Government of Alberta in January 2017. It offered a thirty percent credit to "investors who provide capital to Alberta small businesses doing research, development or commercialization of new technology, new products or new processes" (Alberta Economic Development and Trade 2017, p.1) on income or corporate tax paid to the province[2]. The program was part of the *Investing in a Diversified Economy Act*, which also started the Capital Investment Tax Credit (CITC)[3]. Both programs were phased out in 2019, and no additional funding was given to companies after March 2020. The AITC was communicated to foster investment and employment (Alberta Economic Development and Trade 2017, 2019; Zabjeck 2016).

The program required businesses to register with the government as Venture Capital Corporations (ECC) or Eligible Business Corporations (EBC), which would then be able to raise equity capital from investors. Only investors who had paid corporate or personal taxes in the province were eligible. While the *Investing in a Diversified Economy Act* was passed in January 2017, eligible investments in VCCs and ECCs were available to be claimed as credits retroactively from April 2016 onwards.

To qualify as "small", businesses could not have more than 100 employees. Additionally, they were required to pay at least 50%-75% of wages to employees working in Alberta[4], have at least C$25,000 in equity capital, and at least 80% their assets in Alberta (Alberta Economic

2. Tourism, interactive media, post-production and visual effects industries were also targeted.

3. The CITC returned the value of purchases of machinery, equipment and buildings as a tax credit. While this program may have a spillover effect on innovation through a reduced cost of innovation investment, absent the AITC, there is no reason to believe a broad capital expenditure tax credit would impact innovation products.

4. Depending if the company was an exporter or non-exporter, respectively.

Development and Trade 2019). These companies needed to be engaged in "the process of introducing a new product or production method and making it available to the public market. This includes the commercial production of proprietary technologies that are capable of improving the processing and manufacturing of goods and services."(Alberta Economic Development and Trade 2019, p.19). Mining, financial services and agricultural activities were ineligible for receiving AITC funding[5].

2.2 Intellectual property in Canada

The Canadian Intellectual Property Office (CIPO) is the federal agency responsible for the administration of intellectual property rights in Canada, managing patents, trademarks and industrial designs. Patents protect innovative products, compositions or machines. To apply for a patent, inventors prepare and submit an application to the CIPO.

The parties in an application can be inventors, owners[6], agents, or other applicants[7]. Patent agents are external agents, commonly hired by the inventorship team, to assess the inventors on the application (Putnam 2006). After sending the application, the team receives a filing date[8]. The parties then have a four-year period to request an examination date, when the CIPO will evaluate the invention to grant the patent. If granted, it will be valid for 20 years only within Canada (Abbes, Baldwin, and Leung 2022). The patent protects the invention from being used, made, or sold by others without the inventor's permission.

Canada adheres to international treaties and agreements which govern the level of intellectual property protection in the country. These are the World Intellectual Property Organization (WIPO) treaties, the Paris Convention for the Protection of Industrial Property, and the Patent Cooperation Treaty (PCT). The WIPO treaties are of particular importance, as they allow classifying patents in a standardized way: the International Patent Classification (IPC).

5. The *Alberta Investor Tax Credits Regulation* specifies that "companies needed to be engaged in the research, development and commercialization of proprietary technologies produced within Alberta, including services that are directly associated with the export of the technology and are provided inside or outside of Alberta"(p.9).

6. Inventors typically also hold legal ownership of the patent. See Alam, Dalziel, and Cozzarin (2022) and Beaudry and Schiffauerova (2011) for discussions of foreign ownership of Canadian inventions.

7. These applicants would be categorized as *legal representatives* by the *Patent Act* of Canada. These are heirs, executors, or any other actor who acts on behalf of the inventor in the patent application . Multiple applicants are relevant in the case of a company that hires employees to work on patent applications.

8. Incomplete applications will be returned to the parties for reapplication with a two-month grace period. Applications not sent back by the parties are considered abandoned (Canadian Intellectual Property Office 2021).

There are 8 patent classes, coded A through H, which represent broad categories of inventions. Within each class, there are subclasses and groups[9]. Sections codes, names and descriptions are included in Appendix D.

The role of international treaties also responds to the important role that intellectual property plays in the international context. For example, recent research has shown how Canadian firms underperform vs. their American counterparts due to worse intellectual property frameworks (Carew, Florkowski, and Smith 2006). Further, Canadian firms are more likely to export to countries with stronger intellectual property protections (Rafiquzzaman 2002). An accurate impact evaluation must consider the effects that foreign influences may have on the local intellectual property environment.

2.3 The Scientific Research and Experimental Development Credits

Canada has been characterized as one of the most generous tax jurisdictions for R&D expenditure (McKenzie 2008; Mansfield and Switzer 1985a), which McKenzie (2005) attributes to the government's approach to solving the country's R&D intensity stagnation. According to the Canada Revenue Agency (2023). In 1962, an experimental tax incentive was created after a change to the *Income Tax Act.* This program would undergo various changes over the years, taking the form of a full expenditure deduction plus a tax credit by 1984. The current program's name, the *Scientific Research and Experimental Development Credit*, was given in 1986. The program has been in place since then, with complex rules and regulations that have been amended over the years (Canada Revenue Agency 2015).

Additionally, most provinces offer additional incentives. The Provincial SR&ED tax credits started to be implemented in the late 1980s and are managed by provincial and territorial governments. By the early 2000s, most provinces had adopted them (Warda 2000, 1998; McKenzie 2005). Alberta implemented the program in 2009 (Brouillete 2013).

Given the well-documented effects of these policies on R&D expenditures (Mansfield and Switzer 1985a; Agrawal, Rosell, and Simcoe 2020; Becker 2015), it is sensible to believe that policy efforts like these have an ongoing impact on innovation. It is crucial to consider time

9. A patent may be assigned to more than one IPC section.

trends to control for federal SR&ED changes. Since the provincial programs are frequently reformed (McKenzie 2005), they pose threats to causal identification. This makes the use of event study regressions critical to validate results from a difference-in-differences approach.

3 Empirical Approach

3.1 Data

I employ a novel administrative dataset from the Canadian Intellectual Property Office, the IP Horizons Patent researcher datasets (2023). The data identify patent applications in Canada from 1869 to August 2021, including all involved parties and the application filing data. Parties can be mapped to provinces based on their location, which can be in Canada or other countries.

With these data, I compute quarterly patent application counts at the province level from 2001Q1 to 2021Q2. This period, spanning January 2001 to June 2021, corresponds to the modern Canadian institutional context, as reviewed in Section 2, when most provinces had implemented their SR&ED programs. I assign patents to provinces based on where the majority of parties from patent applications report their location[10]. Further, I drop Newfoundland and Labrador (NL), Prince Edward Island (PE), Yukon (YU) and Nunavut (NU) due to missing observations on explanatory variables.

Patent application counts are my main explained variable. Further, I separate patents by their International Patent Classification (IPC) section as separate explained variables for some models. For explanatory variables, I extract province-level data at the monthly frequency from Statistics Canada and aggregate it at the quarterly frequency. These include data from the Labour Force Survey (LFS), such as labour force characteristics, employment wages, among others. I also consider the consumer price index, international merchandise exports and imports, retail, wholesale and manufacturing trade sales, food services receipts, the new housing price index and electric power generation. I also include the number of business insolvencies as reported by Innovation, Science and Economic Development Canada (2024) and the number of foreign parties involved in patent applications from the IP Horizons data. I aggregate

10. Patent applications without information of party locations or with an equal number of interested parties from two provinces are dropped from the sample.

data at the quarterly level by summing all variables except the consumer and new housing indices, which I average over months. I present descriptive statistics for the sample along with a detailed account of my data sources in Appendix A.

3.2 Identification Strategy

The AITC, as an investor tax credit, did not directly affect innovation inputs such as R&D expenditures. However, since it provided access to financing for innovative firms, it may have affected innovation in the form of patent applications. To estimate this effect, I implement a two-way fixed effects (TWFE) difference-in-differences (DD) design, where I define treatment and control groups based on when the program was passed (2017Q1). While the first investment eligibility date was in 2016, businesses only started receiving AITC funding after 2017Q1, hence any effect would only be observed then. The treatment group is Alberta, and the treatment period is composed of all periods after 2017Q1. The control group is all remaining Canadian provinces in the sample. Treated observations are those from Alberta after 2017Q1, where the AITC may have affected Albertan patent applications. The DD design is implemented in a regression framework according to Equation 1 below.

$$\ln(P_{it} + 1) = \theta_i + \theta_t + \beta T_{it} + \mathbf{x}_{it}^{'}\gamma + u_{it} \tag{1}$$

where P_{it} is patent applications in a province i and period t. θ_i and τ_t are sets of province and period fixed effects. I use a natural logarithm transformation with the addition of one to correct for provinces with small amounts of patent applications on some periods. The logarithm will give percent interpretations to the coefficients on the right-hand side. T_{it} is a binary variable equal to unity for observations for treated observations and zero otherwise. Hence, the estimated parameter $\hat{\beta}$ is the coefficient of interest, which is my estimate for the effect of the AITC on P_{it}. $\mathbf{x}_{it}$ is a vector of time and province-varying controls, as described in the previous subsection, and γ is the associated vector of parameters. u_{it} is a province and time-varying error term. I cluster standard errors at the province and period level, as the variance of the error term may be spatially and temporally correlated.

Table A.2 in Appendix A presents the difference in means between treated and control provinces for all explained variables. This presents the simplest version of the DD estimate, where I compare the average number of patent applications between Alberta and the control provinces before and after the AITC intervention. This simple comparison suggests a small or null effect; the regression analysis described above will provide a more robust estimate, controlling for other factors that may affect patent applications.

Figure 1: Quarterly time series of patent applications between treatment and control groups

Notes: The figure shows the quarterly time series of patent applications between the treatment and control groups from 2001Q1 to 2021Q2. The vertical line represents the start of the AITC intervention in 2017Q1. The treatment group is Alberta, and the control group consists of all remaining provinces except NL, PE, YT and NU.

The key identifying assumption of DD is that absent the intervention, the trend of patent applications in Alberta would follow a similar pattern to that in control provinces. Figure 1 shows the time series of patent applications between Alberta and control provinces. Alberta's patent applications follow a similar pattern to control provinces before the intervention, however, some deviations are present before 2016Q2.

To allay the concern of unobservable factors impacting patent application trends across provinces, I estimate event study regressions following Equation 2 below and provide supporting evidence for causal identification of $\hat{\beta}$.

$$\ln(P_{it} + 1) = \theta_i + \tau_t + \beta_t(\tau_t \cdot A_t) + \mathbf{x}_{it}^{'}\gamma + u_{it} \tag{2}$$

$\theta_i, \tau_t, \mathbf{x}_{it}, \gamma$ and u_{it} represent the same as in Equation 1. τ_t has its reference level set to one period before the treatment start period (2016Q4). A_t is a binary variable equal to unity for Alberta observations and zero otherwise. $\tau_t \cdot A_t$ is the interaction term between these two variables. β_t is the associated vector of coefficients, which will show the difference between the treatment and control groups in the explained variable for all t. For these regressions, I show the values of the interaction terms in event study plots, along with 95% confidence intervals. I cluster standard errors at the province and period level.

Evidence in favour of the identifying assumption will be observed if the β_t before 2016Q4 are not statistically significant. This supports the idea that Alberta had no significant differences in the trend of patent applications to other provinces before the intervention. Thus, I use the event study regressions to provide evidence of the causal identification of the effect of the AITC. Further, I use event study regressions in the form of Equation 2 to examine the effectiveness of the AITC by looking at post-treatment interaction terms.

3.3 Patent parties and province-month panel

I perform two robustness checks on DD and event study analyses to ensure the validity of my results. First, to the extent that results could be driven by the patent-province mapping, I consider the number of Canadian parties involved in a patent application as an alternative explained variable. I separate parties by type (all parties, inventors, owners and applicants[11]). Table A.2 also presents the difference in means between treated and control provinces for parties involved in patent applications.

Second, I reestimate models on a province-month panel, to ensure that the results are not driven by the aggregation of data at the quarterly level. I present descriptive statistics of the monthly data in Appendix A.

11. I do not consider agents as a separate category due to them being hired professionals, which is not informative about the patent application team.

4 Results

4.1 Patent applications

Table 1 presents results of the estimation of Equation 1 using patent applications as the explained variable. Specification (1) includes a baseline result with no control variables. Specification (2) includes economic controls to account for factors that may affect the comparability of the treatment and control groups regarding firm activity and overall economic trends which vary across time and provinces. The number of foreign parties involved in patent applications is also included, to control for foreign influences. Specification (3) considers additional controls, which are included in case the previous ones did not account for differences in trends due to reasons other than the economy, or that economic activity is not well captured by standard economic variables in Specification (2).

The DD estimate (Treated) shows that the intervention led to a -9.3% to +1.1% change in Alberta patent applications. The baseline and additional controls specifications show a negative effect, while the other specification shows a positive one. Only the baseline DD specification shows a statistically significant effect, which disappears after controlling for other factors. Standard errors for the coefficient of interest are small compared to those of the controls, showing that $\hat{\beta}$ is estimated with a fairly good level of precision.

I display the results of the event study regressions in Figure 2, which plots the $\hat{\beta}_t$ interaction term coefficients in 2 with the same controls as the specifications in Table 1. For specifications (2) and (3) there is no significant difference in patent applications between treatment and control groups for most pre-intervention periods. This supports the key identifying assumption of the DD design, supporting the causal identification of $\hat{\beta}$. The baseline model does show several pre-policy periods where the treatment and control groups diverge, underscoring the importance of including controls in the model. However, in all specifications, there are particular periods for which a statistically significant difference exists. This can be due to random noise or to a temporary real effect. Since it is only one period that disappears later, I do not consider it a substantial threat to the causal identification of $\hat{\beta}$.

Regarding the effect of the policy itself, results point toward an overall null effect in the

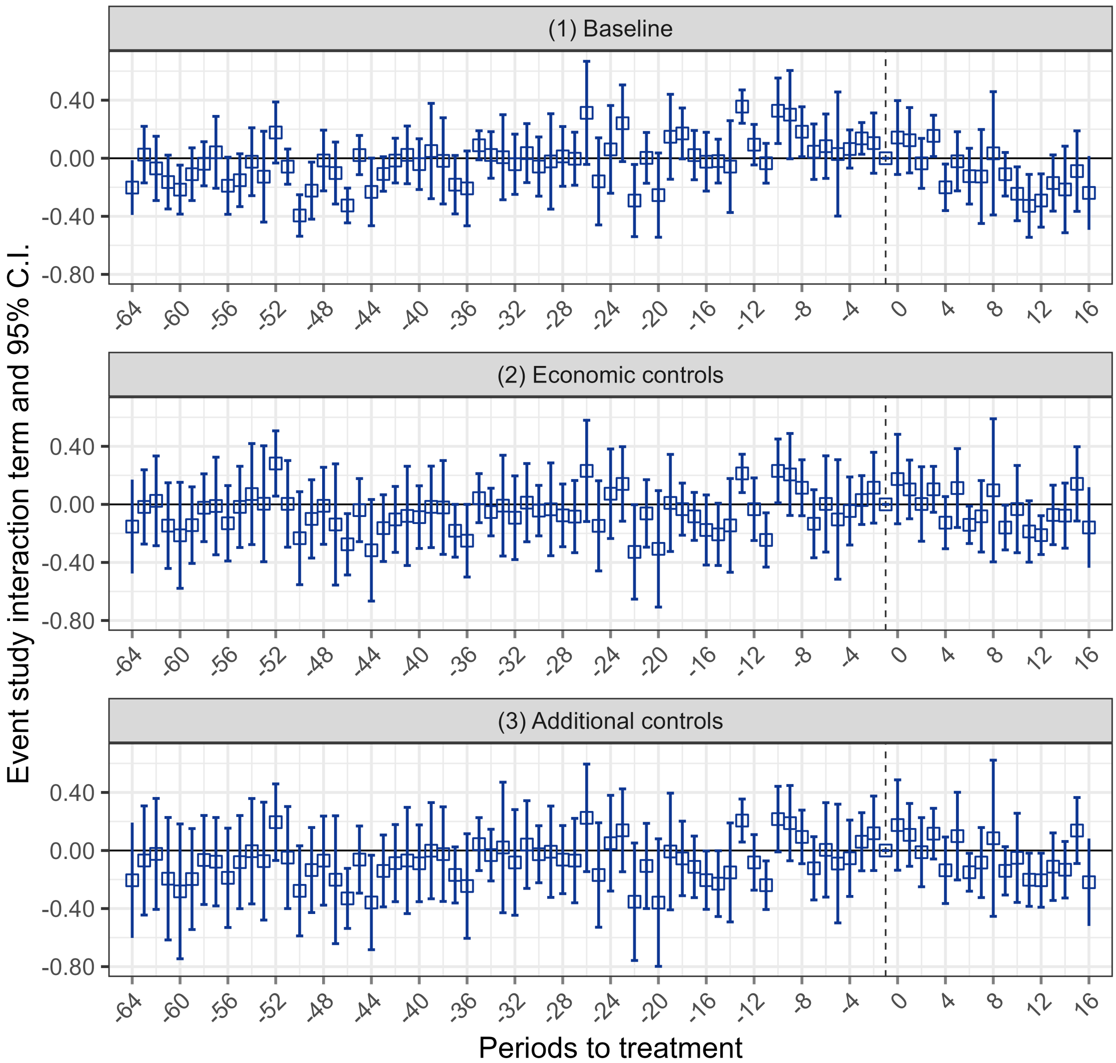
Table 1: Difference-in-differences (DD) specifications for quarterly patent applications

	(1)	(2)	(3)
Treated	-0.093^{*}	0.001	-0.011
	(0.042)	(0.066)	(0.076)
Ln Full-time employment		0.756	1.032
		(0.644)	(0.646)
Ln Median wage		1.235^{**}	1.107^{**}
		(0.387)	(0.445)
CPI		-0.015^{**}	-0.007
		(0.005)	(0.008)
Ln +1 Business insolvencies		-0.065^{**}	-0.051^{*}
		(0.027)	(0.023)
Ln Intl. exports		-0.081	-0.079
		(0.097)	(0.125)
Ln Intl. imports		0.016	0.022
		(0.126)	(0.127)
Ln Retail sales		-0.279	0.094
		(0.421)	(0.492)
Ln Wholesale sales		-0.150	-0.229
		(0.156)	(0.139)
Ln Manufacturing sales		0.275	0.210
		(0.153)	(0.146)
Ln +1 Foreign patent parties		0.141^{***}	0.135^{***}
		(0.016)	(0.016)
Ln International travellers			-0.129^{***}
			(0.034)
Ln Arriving vehicles			0.007
			(0.004)
Ln Electric power generation			0.078
			(0.115)
Ln Average actual hours			0.109
			(0.277)
New housing price index			-0.003
			(0.002)
Ln Food services receipts			-0.080
			(0.201)
Ln Average job tenure			-0.424
			(0.373)
Explained variable		ln(Patents + 1)	
N	656	656	656
Adj. R^2	0.975	0.980	0.980
Adj. within R^2	0.002	0.205	0.210
RMSE	0.206	0.182	0.180

Notes: Clustered standard errors at the province and quarter level shown in parentheses. All specifications include fixed effects for provinces and quarters. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

event study plots as well. There are marginally negative effects on some periods, which appear next to periods with null effects. This evidence supports the null effect found in the DD specifications (2) and (3), which is consistent with the fact that economic factors (such as business insolvencies, wage, employment, etc.) and foreign influences (the number of foreign parties in patent applications) control for differences between treated and untreated observations.

Figure 2: Event study plots for quarterly patent applications



Notes: The figure shows the estimated coefficients of the interaction term between period and treatment binary variables in Equation 2 for each quarter. The points represent the point estimate, while the error bars represent the 95% confidence cluster-robust interval. The vertical line represents the start of the AITC intervention in 2017Q1, with the reference level being the quarter before the intervention. Baseline, economic, and additional controls specifications include the controls seen in specifications (1) through (3) in Table 1.

4.2 Separating by International Patent Classifications (IPC)

Table 2: Difference-in-differences results for quarterly patent applications by IPC section

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treated	0.409***	0.329	0.068	0.334**	−0.577***	0.164	−0.138	0.229
	(0.077)	(0.215)	(0.186)	(0.138)	(0.062)	(0.107)	(0.193)	(0.149)
IPC	A	B	C	D	E	F	G	H
N	656	656	656	656	656	656	656	656
Adj. R^2	0.913	0.911	0.879	0.355	0.915	0.875	0.910	0.908
Adj. within R^2	0.109	0.054	0.082	0.037	0.064	0.021	0.061	0.064
RMSE	0.324	0.355	0.381	0.355	0.360	0.394	0.395	0.409

Notes: All specifications include controls in Specification (3) of Table 1, not shown for brevity, and fixed effects for provinces and quarters. Clustered standard errors at the province and quarter level shown in parentheses. Sections of the IPC are A: Human necessities, B: Performing Operations & transporting, C: Chemistry & Metallurgy, D: Textiles & paper, E: Fixed constructions, F: Mechanical engineering; G: Physics and H: Electricity. Patents with multiple sections are not included. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

In Table 2, I present the results of estimating Equation 1 for different IPC section patent applications, including only the controls of Specification (3) in Table 1. The results show that the AITC intervention had a null effect on most of the IPC sections except A, D and E, corresponding to human necessities, textile/paper and fixed construction inventions. The effects on sections A and D are positive while the effect is negative on section E inventions.

Approximately, it would appear that the positive effect on human necessity and textile applications is larger than the negative effect on fixed construction applications. However, given that there is a smaller number of patents per IPC section for all provinces in every period, I am underpowered to detect small effects on other sections. Effects on other sections could be negative, thus explaining the null effect on total patents.

The event study regressions in Figure 3 provide additional insight into the intervention's effect on patent applications by IPC section. The figure displays the same coefficients and confidence intervals as those in Figure 2, now separating by IPC section and restricting to the specification with additional controls.

Human necessity (A) inventions, which include agriculture, medicine and apparel-related inventions, saw a greater amount of patent applications in most post-intervention periods compared to the control group. However, pre-intervention periods do not provide evidence in support of the common trends assumption, which may be driving a spurious positive effect in the post-intervention periods. Regarding textile and paper (D) inventions, the event study plot shows very large increases in patent applications in some intervention periods compared to the control group. However, these increases are confined to the last few periods, with the first quarters after the intervention showing no significant differences.

The offsetting negative effect on fixed construction (E) inventions is difficult to interpret in the event study plot. Almost no post-intervention period shows a significant difference between the treatment and control groups. However, the DD specification picks up a negative effect because of large positive differences in the pre-intervention periods. I cannot reject that the negative effect is due to factors other than the AITC intervention.

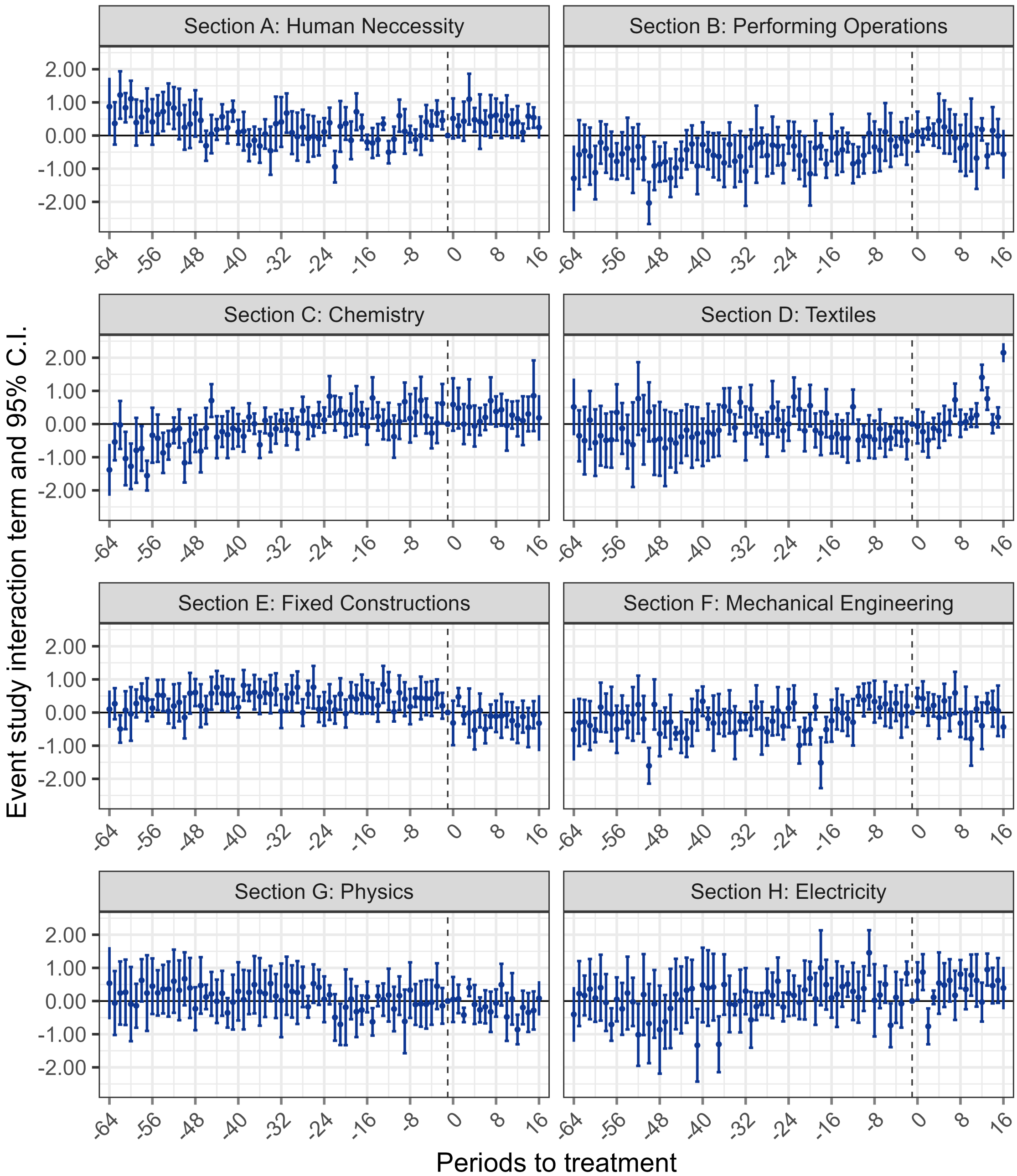
In general, while the DD estimates would point to a significant effect of the AITC on some IPC section patent applications, closer inspection of the event study plots shows that the effect cannot be supported by a common trends assumption. Other factors may be driving the results which are unobserved in the data and specific to these inventions.

4.3 Robustness checks

Appendix B presents the results of the DD specifications and event studies for number of parties in patent applications as explained variables. All models use the controls in Specification (3) of Table 1. I consider total parties in patent applications and also separate by specific types: inventors, owners and applicants. All DD specifications show a null effect of the policy with a slight increase in standard errors. This is understandable given that the number of interested parties as an explained variable proxies for both the number of patent applications in a province but also for the size of the application team. This makes the use of the natural logarithm transformation crucial for a better interpretation of the DD estimate, as the number of parties is an inflated indicator of innovation.

Event study plots for parties show that the effect is null for most post-policy periods. Pre-policy trends show less consistency between treatment and control groups, particularly 52 to 36 periods before the AITC started. Because this difference disappears in the following quarters, I do not see it as a substantial threat to identification. Overall, these results show evidence that my mapping of patents to provinces does not drive my results.

Figure 3: Event study plot for quarterly patent applications by IPC section



Notes: The figure shows the estimated coefficients of the interaction term between period and treatment binary variables in Equation 2 for each quarter, separating by IPC section. The points represent the point estimate, while the error bars represent the 95% confidence cluster-robust interval. The vertical line represents the start of the AITC intervention in 2017Q1 with the reference level being the quarter before the intervention. Controls are the same as those in Specification (3) in Table 1.

Appendix C reproduces the DD specifications and event study regression using the province-month panel. Monthly DD specifications show similar results in terms of statistical significance compared to results in Table 1. This means that the additional precision does not change the existence of a null result. Regarding the event study plot, the pre-intervention months are much less stable than in the quarterly case. There are statistically significant differences in many periods before January 2017, which present themselves in an almost seasonal nature: differences start being relatively large, but as months pass they become smaller until being null. This explains why the quarterly aggregation does not show an unstable pre-intervention trend. I discuss the implications of this issue in the conclusion. In the post-intervention periods, there were months in which Alberta had fewer patent applications than the control provinces, but in the last period, these differences were not significant. Overall, post-intervention periods do not show a significant deviation from the quarterly results.

Concerning IPC section patents, the monthly DD specifications show significant effects for all sections but C and G. However, the event study plots for each section show similar pre-intervention patterns to those in the quarterly case. Most pre-intervention periods display statistically significant differences between the treatment and control groups. These differences seem to be larger and persist for a longer amount of periods than in the quarterly case. This is likely due to the increased number of periods in the monthly data, which allows for more noise to be picked up. The quarterly aggregation smooths out these differences. I cannot reject that the statistically significant effects in the DD specifications for each section are due to factors other than the AITC intervention. Hence, I cannot conclude that the AITC had a significant effect on patent applications by IPC section.

5 Conclusion

This paper estimates the impact of an investment tax credit in Canada, the Alberta Investor Tax Credit (AITC) on innovation outcomes. Exploiting variation in patent applications from a novel administrative dataset, I use difference-in-differences and event study regression to estimate the effect of the policy. I find that the AITC had a null effect on patent applications from

Albertan parties. I find evidence that the policy increased applications for textile and human necessity inventions, yet decreased applications for fixed construction inventions. However, due to uncommon trends between treatment and control groups, I cannot verify whether these effects are due to the policy or unobserved factors. Hence, I provide evidence that supports a null total effect of the AITC on patent applications. These results are robust to the use of patent application parties as the explained variable, which ensures that the null effect is not driven by my mapping of patent applications to provinces. Further, the post-intervention effects are validated using monthly data on patent applications.

These results challenge the effectiveness of tax credits aimed to promote innovation. If the AITC had a positive effect on R&D expenditure, an increase in patent applications would be expected. Data limitations do not allow me to validate the positive effect of R&D tax credits from the literature, however, the null effect on patent applications suggests that any increased effect on R&D expenditure did not translate to increased patent applications. A possible mechanism for this result is the relabeling of general business expenditures as R&D in the presence of fiscal incentives (Chen et al. 2021). Given that the AITC required businesses to undertake R&D activities to be eligible for AITC investment, it is possible that this relabeling occurred, which allowed businesses that were not innovative to claim the tax credit. Opportunistic behaviour by businesses to obtain AITC funding would also explain the null effect, even in the presence of non-R&D innovation (Xie, Wang, and Jiao 2019). This paper is a first step in understanding how non-traditional fiscal incentives can affect innovation outcomes.

My paper's contribution to the literature is threefold. By using patent application counts, I focus on a short-term innovation outcome, which allows me to avoid the expense relabeling of firms to leverage tax savings and to include innovation not produced by an R&D process. Further, I analyze an investment tax credit, an understudied policy in the literature. To my knowledge, no other paper has focused on how providing easier access to financing for innovative businesses has affected innovation outcomes. While traditional tax credits have typically not had an innovation motive, the introduction of the AITC shows how governments can use tax credits to promote innovation in non-traditional ways. Finally, I extend the literature on Canadian innovation policy, which has focused on the Scientific Research and Experimental Development (SR&ED) programs. By studying the AITC, I motivate the discussion on how other fiscal incentives at the provincial level can affect innovation outcomes.

Ultimately, while it is valuable to observe patents as an innovation outcome, these results should be validated with the traditional R&D expenditure outcome. My inability to observe R&D expenditure at the province level due to data limitations allows for other mechanisms that can explain the null effect, which do not relate to the ineffectiveness of the AITC intervention. One is the possibility that patent data does not capture innovation that happens outside the patent system (Moser 2013). It is important to validate the paper's results by examining the effectiveness of the intervention using financial statement data from small firms. By doing this, it will be possible to determine the mechanism through which the null effect is observed. In the same line, there is evidence that patent activity does not reflect innovation but strategic responses to regulatory changes (Graham and Mowrey 2004). Further, recent evidence shows that patenting activity has slightly decreased in Canada, in favour of trademarks and industrial designs (Canadian Intellectual Property Office 2022). To better understand the value of patent counts as measures of innovation, trademarks and industrial designs should be used as explained variables.

Concerning threats to causal identification, while the results from my event study regressions support causal identification in the quarterly data and the total patent applications, the results are less conclusive for other cases. The existence of a predictable deviation from common trends between Alberta and the control provinces in the monthly data might mean that Alberta is more sensitive to seasonal shocks to innovation and research activities. Reforms in intellectual property law as well as reforms in the SR&ED programs in any Canadian province could be causing this deviation. Further, the existence of persistent deviations from common trends across IPC sections suggests that the AITC may have had heterogeneous effects on different types of innovation, which I am unable to identify.

These limitations suggest that the use of a TWFE difference-in-differences estimator may be insufficient for this type of setting. Future research should focus using other methods, such as matching (Caliendo and Kopeinig 2008) and synthetic control (Abadie, Diamond, and Hainmueller 2010) for the definition of better control groups to best ensure causal identification. Using these methods will also allow for the evaluation of policies on outcomes that are fundamentally unstable across time in the institutional context, such as employment. Further, being able to identify the effects of policies across different types of inventions will be able to determine if governments crowd out certain types of innovation with fiscal incentives.

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A Appendix: Data sources and additional descriptive statistics

Table A.1: Descriptive statistics for the province-quarter sample

	Mean	SD	Min	Median	Max
Ln +1 Patent applications	4.261	1.405	1.099	4.107	6.691
Ln Full-time employment	8.026	1.034	6.726	7.831	9.814
Ln Median wage	2.949	0.192	2.523	2.956	3.395
CPI	119.145	12.668	95.400	119.400	148.900
Ln +1 Business insolvencies	4.403	1.396	0.693	4.197	6.957
Ln Intl. exports	15.810	1.139	13.694	15.848	17.804
Ln Intl. imports	15.646	1.198	13.715	15.369	18.372
Ln Retail sales	15.963	1.028	14.424	15.774	17.913
Ln Wholesale sales	15.910	1.292	13.907	15.892	18.490
Ln Manufacturing sales	16.027	1.179	14.398	15.729	18.213
Ln International travellers	12.470	1.779	4.344	12.387	15.929
Ln Arriving vehicles	11.944	3.562	0.000	12.516	15.801
Ln Electric power generation	16.213	0.997	14.344	16.219	17.990
Ln Average actual hours	3.545	0.050	3.311	3.550	3.676
New housing price index	88.064	16.987	42.900	94.250	129.500
Ln Food services receipts	13.737	1.108	12.255	13.575	15.857
Ln Average job tenure	4.636	0.088	4.399	4.653	4.830
Ln +1 Foreign patent parties	3.609	1.918	0.000	3.842	6.671

Notes: All statistics based on a balanced panel of N = 656 province-quarter observations from 2001Q1 to 2021Q2. The sample includes all Canadian provinces except NL, PE, YU and NU.

Table A.2: Differences in means between treated and control provinces in province-quarter panel

Treatment		Pre	Post
Control	Ln +1 Patent applications	4.119	4.060
	Ln +1 Interested parties	5.674	5.459
	Ln +1 Inventors	4.732	4.730
	Ln +1 Applicants	4.155	4.095
	Ln +1 Owners	4.723	4.167
	Ln +1 Total population	8.636	8.735
	Ln +1 Section A applications	2.554	2.588
	Ln +1 Section B applications	2.237	2.007
	Ln +1 Section C applications	1.458	1.301
	Ln +1 Section D applications	0.347	0.167
	Ln +1 Section E applications	1.499	1.502
	Ln +1 Section F applications	1.613	1.399
	Ln +1 Section G applications	1.841	2.016
	Ln +1 Section H applications	1.611	1.373
	Ln +1 Multiple section applications	2.873	3.006
Treatment	Ln +1 Patent applications	5.380	5.228
	Ln +1 Interested parties	6.800	6.645
	Ln +1 Inventors	5.731	5.930
	Ln +1 Applicants	5.380	5.245
	Ln +1 Owners	5.886	5.322
	Ln +1 Total population	9.050	9.241
	Ln +1 Section A applications	2.714	2.893
	Ln +1 Section B applications	2.939	2.992
	Ln +1 Section C applications	2.634	2.626
	Ln +1 Section D applications	0.181	0.301
	Ln +1 Section E applications	4.076	3.699
	Ln +1 Section F applications	2.513	2.377
	Ln +1 Section G applications	3.067	2.844
	Ln +1 Section H applications	1.945	1.780
	Ln +1 Multiple section applications	4.104	4.096

Notes: Calculations based on a balanced panel of $N = 656$ province-monthly observations from 2001Q1 to 2021Q2. The sample includes all Canadian provinces except NL, PE, YU and NU. The treatment group is Alberta, and the control group consists of all remaining provinces. Post-intervention periods are those after 2017Q1.

Table A.3: Data sources

Variable	Source	Note
Ln + 1 Patent Applications	IP Horizons (CIPO 2023)	Linking `PT_Main` and `PT_Interested_Party`.
Ln +1 Patent parties by type	IP Horizons (CIPO 2023)	Linking `PT_Main` and `PT_Interested_Party`.
Ln +1 Foreign patent parties	IP Horizons (CIPO 2023)	Linking `PT_Main` and `PT_Interested_Party`.
Ln + 1 Patent Applications by IPC section	IP Horizons (CIPO 2023)	Linking `PT_Main`, `PT_Interested_Party` and `PT_IPC_Classification`.
Ln Full-time employment	Statistics Canada (2024d)	From the Labour Force Survey (LFS), data table 14-10-0287-03.
Ln Median wage	Statistics Canada (2024c)	From the LFS, data table 14-10-0063-01.
Consumer price index (CPI)	Statistics Canada (2024f)	From data table 18-10-0004-01.
Ln Intl. exports	Statistics Canada (2024a)	From data table 12-10-0175-01.
Ln Intl. imports	Statistics Canada (2024a)	From data table 12-10-0175-01.
Ln Retail sales	Statistics Canada (2023)	From data table 20-10-0008-01.
Ln Wholesale sales	Statistics Canada (2024h)	From data table 20-10-0074-01.
Ln Manufacturing sales	Statistics Canada (2024e)	From data table 16-10-0048-01.
Ln Arriving vehicles	Statistics Canada (2024k)	From data table 24-10-0052-01.
Ln International travellers	Statistics Canada (2024j)	From data table 24-10-0005-01.
Ln Electric power generation	Statistics Canada (2008; 2024)	Binding data tables 25-10-0001-01 and 25-10-0015-01.
New housing price index	Statistics Canada (2024g)	From data table 18-10-0205-01.
Ln Food services receipts	Statistics Canada (2024i)	From data table 21-10-0019-01.
Ln Average job tenure	Statistics Canada (2024b)	From data table 14-10-0050-01.
Ln +1 Business insolvencies	ISED (2024)	Extracted from the Open Government API using the *rgovcan* R package.

Notes: The IP Horizons Patent Researcher data compose three tables: `PT_Main`, `PT_Interested_Party` and `PT_IPC_Classification`.. `PT_Main` is the master table that contains the basic information on patent applications filed, with a common identifier ("patent number") to link to other tables. Data from Statistics Canada were extracted using the *statcanR* R package.

Table A.4: Descriptive statistics for variables in the province-month panel

	Mean	SD	Min	Median	Max
Ln +1 Patent applications	3.187	1.400	0.000	3.178	5.714
Ln Full-time employment	6.927	1.034	5.614	6.733	8.722
Ln Median wage	2.945	0.193	2.487	2.956	3.411
CPI	118.994	12.717	93.400	119.000	148.900
Ln +1 Business insolvencies	3.327	1.388	0.000	3.135	5.974
Ln Intl. exports	14.709	1.141	12.585	14.754	16.767
Ln Intl. imports	14.543	1.204	12.453	14.274	17.340
Ln Retail sales	14.864	1.028	13.312	14.691	16.902
Ln Wholesale sales	14.811	1.292	12.762	14.785	17.400
Ln Manufacturing sales	14.928	1.179	13.241	14.689	17.127
Ln International travellers	11.367	1.790	2.944	11.293	14.833
Ln Arriving vehicles	10.784	3.625	0.000	11.436	14.855
Ln Electric power generation	15.112	0.999	13.197	15.088	16.981
Ln Average actual hours	3.514	0.059	3.235	3.517	3.676
New housing price index	87.826	17.020	42.500	94.100	129.500
Ln Food services receipts	12.638	1.107	10.911	12.462	14.766
Ln Average job tenure	4.634	0.089	4.373	4.651	4.847
Ln +1 Foreign patent parties	2.545	1.862	0.000	2.773	5.927

Notes: All statistics based on a balanced panel of N = 1,968 province-monthly observations from January 2001 to June 2021. The sample includes all Canadian provinces except NL, PE, YT, and NU.

Table A.5: Differences in means between treated and control provinces in province-month panel

Treatment		Pre	Post
Control	Ln +1 Patent applications	3.048	2.990
	Ln +1 Interested parties	4.526	4.314
	Ln +1 Inventors	3.604	3.606
	Ln +1 Applicants	3.074	3.018
	Ln +1 Owners	3.608	3.083
	Ln +1 Total population	7.537	7.637
	Ln +1 Section A applications	1.641	1.660
	Ln +1 Section B applications	1.388	1.252
	Ln +1 Section C applications	0.827	0.732
	Ln +1 Section D applications	0.137	0.060
	Ln +1 Section E applications	0.843	0.831
	Ln +1 Section F applications	0.942	0.797
	Ln +1 Section G applications	1.140	1.280
	Ln +1 Section H applications	1.027	0.821
	Ln +1 Multiple section applications	1.918	2.034
Treatment	Ln +1 Patent applications	4.281	4.131
	Ln +1 Interested parties	5.691	5.539
	Ln +1 Inventors	4.622	4.821
	Ln +1 Applicants	4.279	4.148
	Ln +1 Owners	4.781	4.225
	Ln +1 Total population	7.952	8.143
	Ln +1 Section A applications	1.681	1.832
	Ln +1 Section B applications	1.900	1.963
	Ln +1 Section C applications	1.602	1.592
	Ln +1 Section D applications	0.062	0.100
	Ln +1 Section E applications	2.984	2.608
	Ln +1 Section F applications	1.488	1.396
	Ln +1 Section G applications	2.014	1.816
	Ln +1 Section H applications	1.032	0.898
	Ln +1 Multiple section applications	3.013	3.007

Notes: Calculations based on a balanced panel of N = 1,968 province-monthly observations from January 2001 to June 2021. The sample includes all Canadian provinces except NL, PE, YT and NU. The treatment group is Alberta, and the control group includes all remaining provinces. Post-intervention periods are those after April 2016.

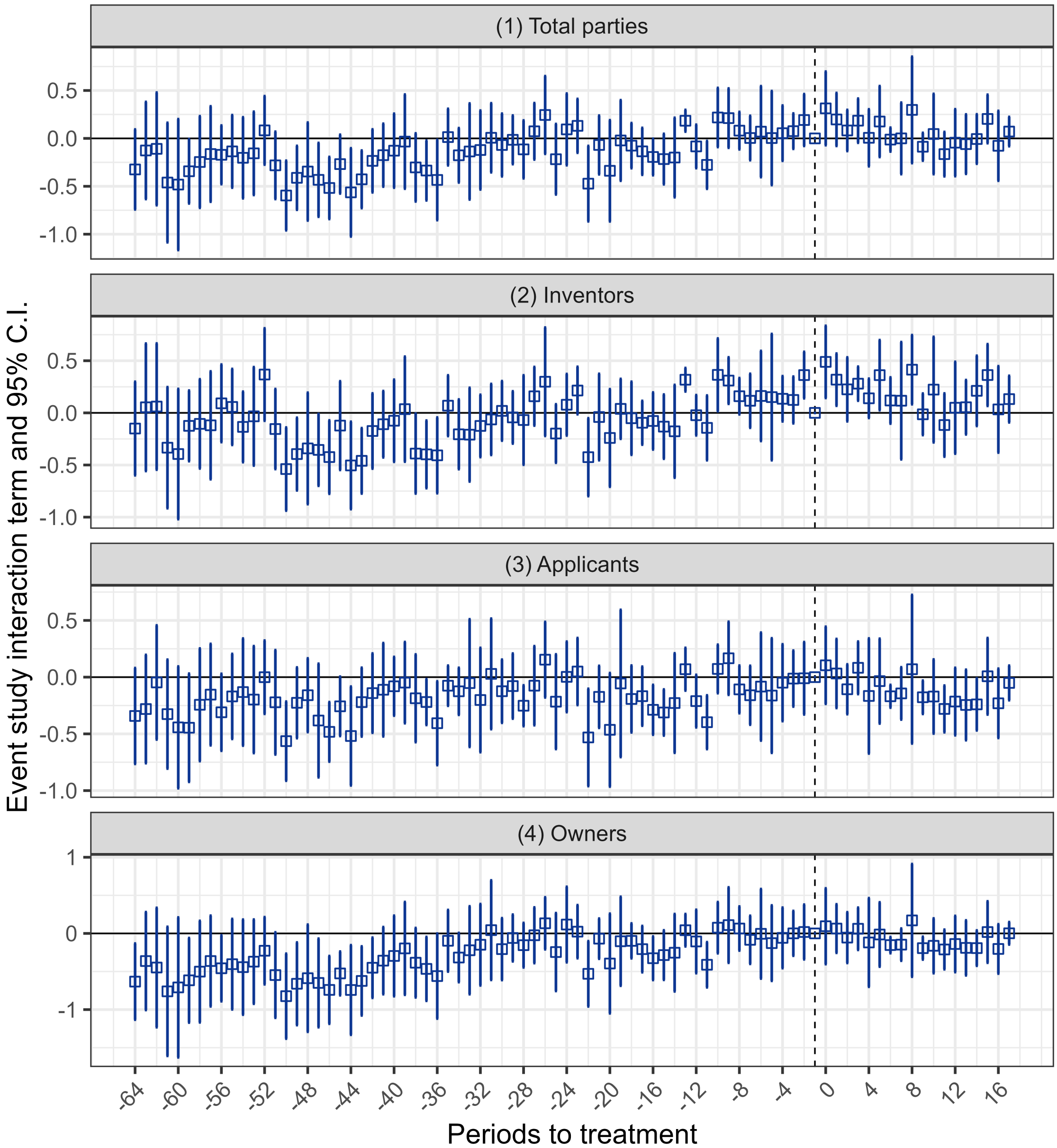
B Appendix: Patent parties models

Table B.1: Difference-in-differences specifications for quarterly patent parties

	(1)	(2)	(3)	(4)
Treated	0.082	0.149	0.007	0.012
	(0.101)	(0.117)	(0.079)	(0.096)
Party type	Total	Inventors	Applicants	Owners
N	656	656	656	656
Adj. R^2	0.974	0.969	0.969	0.971
Adj. within R^2	0.136	0.130	0.094	0.148
RMSE	0.210	0.229	0.220	0.228

Notes: All specifications include controls in Specification (3) of Table 1, not shown for brevity and fixed effects for provinces and quarters. Clustered standard errors at the province and quarter level shown in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Figure B.1: Event study plot for quarterly parties in patent parties



Notes: The figure shows the estimated coefficients of the interaction term between period and treatment binary variables in Equation 2 for each quarter. The points represent the point estimate, while the error bars represent the 95% confidence cluster-robust interval. The vertical line represents the start of the AITC intervention in 2017Q1, with the reference level being the quarter before the intervention. Baseline, economic, and additional controls specifications include the controls seen in specifications (1) through (3) in Table 1.

C Appendix: Province-month panel results

Table C.1: DD specifications for monthly patent applications

	(1)	(2)	(3)
Treated	−0.092*	0.052	0.040
	(0.041)	(0.070)	(0.082)
Explained variable		ln(Patents + 1)	
Controls	None	Economic	Economic + Additional
N	1968	1968	1968
Adj. R^2	0.942	0.952	0.952
Adj. within R^2	0.001	0.168	0.176
RMSE	0.314	0.286	0.283

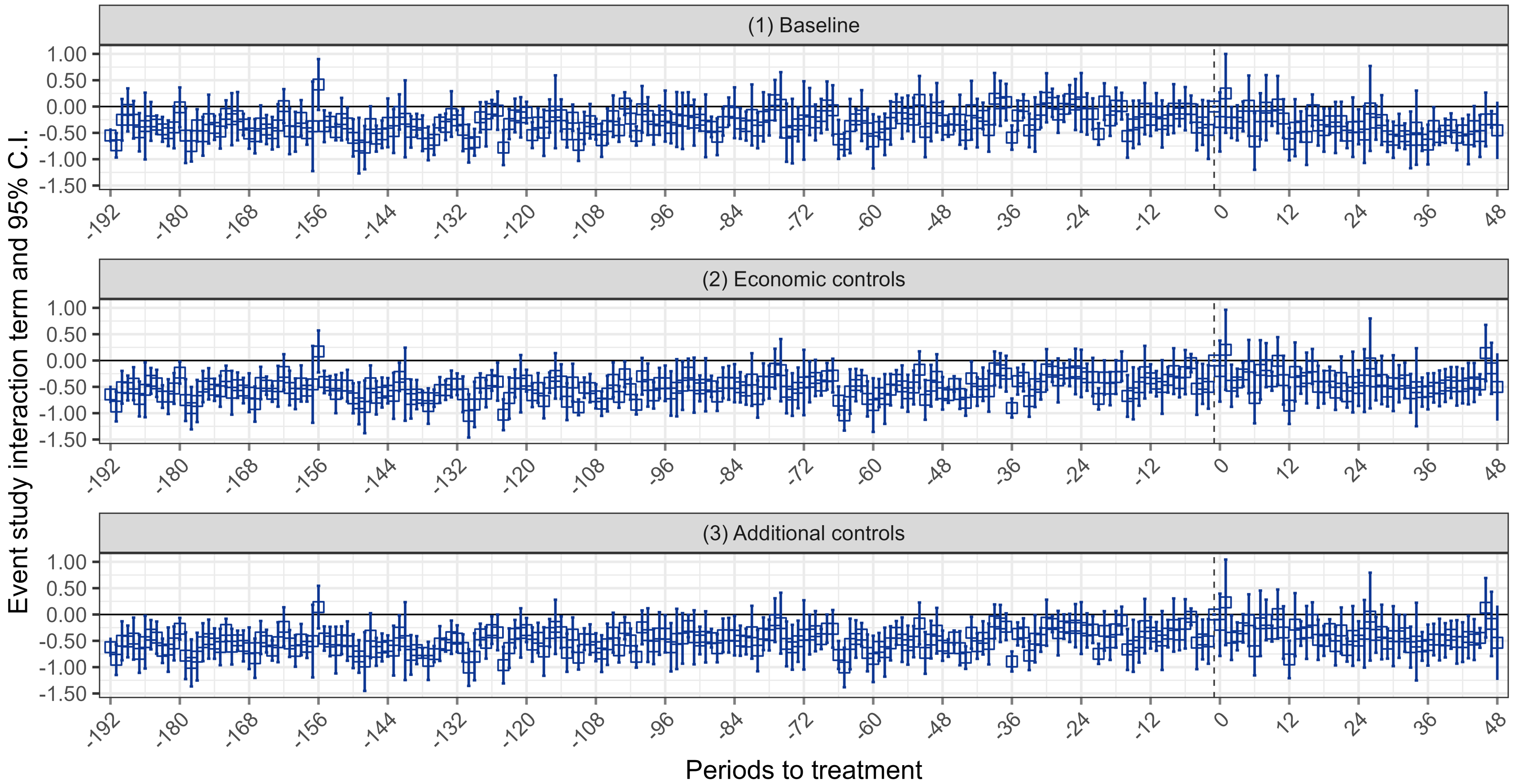
Notes: Clustered standard errors at the province and monthly level shown in parentheses. Specifications include fixed effects for provinces and months and controls for their quarterly counterpart in Table 1. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table C.2: Difference-in-differences results for monthly patent applications by IPC section

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treated	0.290***	0.308**	−0.013	0.134**	−0.513***	0.220**	−0.189	0.195*
	(0.063)	(0.130)	(0.127)	(0.050)	(0.074)	(0.087)	(0.107)	(0.100)
IPC	A	B	C	D	E	F	G	H
N	1968	1968	1968	1968	1968	1968	1968	1968
Adj. R^2	0.823	0.852	0.767	0.164	0.850	0.774	0.877	0.860
Adj. within R^2	0.048	0.037	0.051	0.018	0.057	0.014	0.045	0.057
RMSE	0.414	0.396	0.395	0.248	0.380	0.405	0.374	0.393

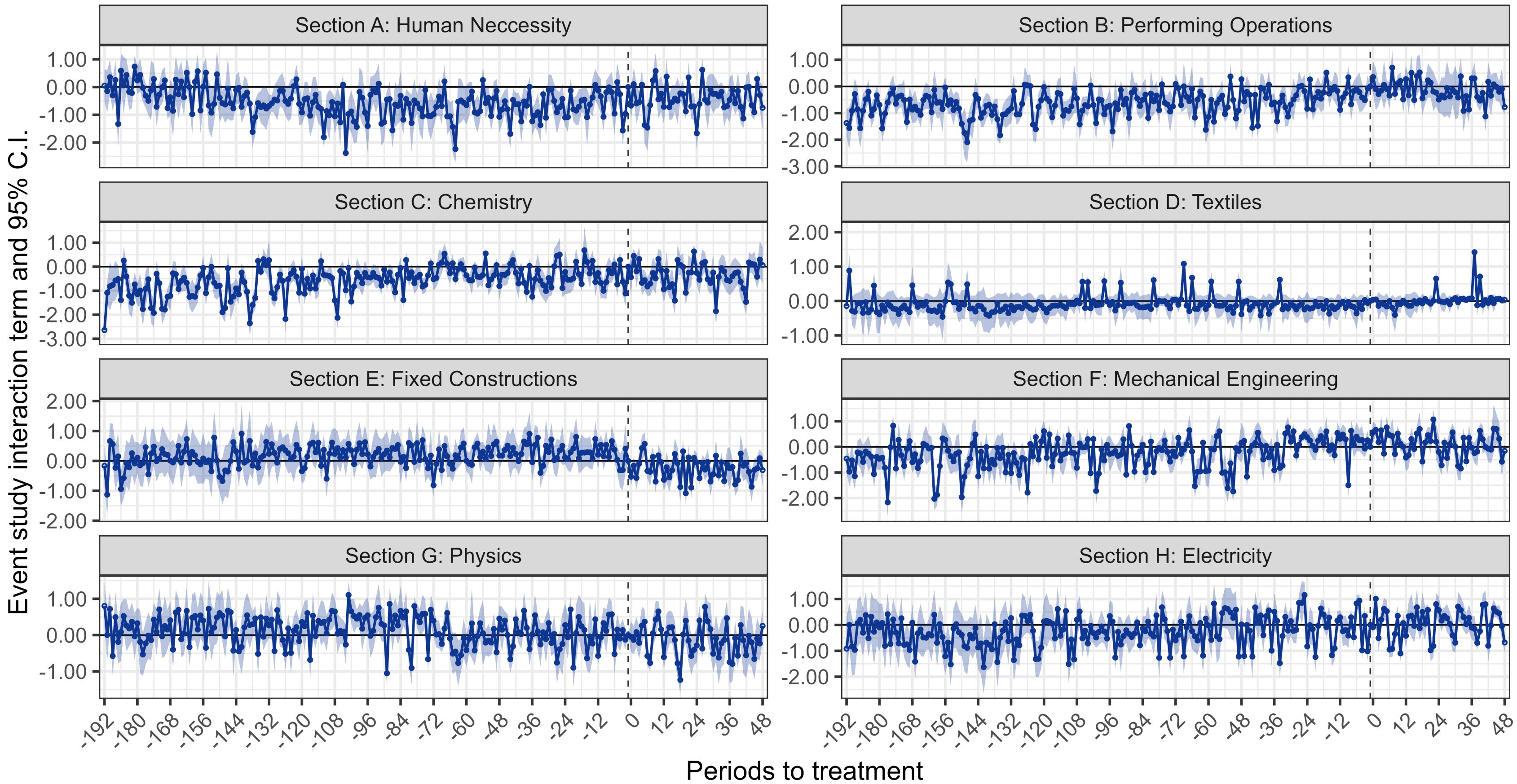
Notes: All specifications include controls in Specification (3) of Table C.1, not shown for brevity and fixed effects for provinces and months. Clustered standard errors at the province and month level are shown in parentheses.
Sections of the IPC are A: Human Necessities, B: Performing Operations; Transporting, C: Chemistry; Metallurgy, D: Textiles; Paper, E: Fixed Constructions, F: Mechanical Engineering; G: Physics, H: Electricity. Patents with multiple sections are not included. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Figure C.1: Event study plot for monthly patent applications



Notes: The figure shows the estimated coefficients of the interaction term between period and treatment binary variables in Equation 2 for each month. The points represent the point estimate, while the error bars represent the 95% confidence cluster-robust interval. The vertical line represents the start of the AITC intervention in January 2017, with the reference level being the month before the intervention. Baseline, economic, and additional controls specifications include the controls seen in specifications (1) through (3) in Table C.1.

Figure C.2: Event study plot for monthly patent applications by IPC section



Notes: The figure shows the estimated coefficients of the interaction term between period and treatment binary variables in Equation 2 for each month, separated by IPC section. The lines represent point estimates, while the shaded areas represent the 95% confidence cluster-robust intervals. The vertical line represents the start of the AITC intervention in January 2017, with the reference level being the quarter before the intervention. Controls are the same as those in Specification (3) in Table 1.

D Appendix: International Patent Classification Sections

Table D.1: IPC section codes and names

IPC Section	Section name
A	Human Necessities
B	Performing Operations; Transporting
C	Chemistry; Metallurgy
D	Textiles; Paper
E	Fixed Constructions
F	Mechanical Engineering; Lighting; Heating; Weapons; Blasting
G	Physics
H	Electricity

Notes: Sourced from World Intellectual Property Organization (2024). A patent application may be assigned to multiple sections.