Do fiscal incentives affect innovation? The effects of the Alberta Investor Tax Credit on patents

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The idea that positive spillover from research efforts disincentivizes its private sector investment has led to a widespread support for fiscal incentives for innovation. While the literature on R&D tax credits is extensive, mostly finding positive effects, the effects of alternative innovation policies are understudied. I examine the impact of the Alberta Investor Tax Credit (AITC) in Canada, which provided a tax credits to investment in innovative businesses. Exploiting variation from patent application counts, I find that the AITC had heterogeneous effects across International Patent Classification (IPC) section. Human neccessity patents increased by 0.5% and textile patents by 0.3%, while fixed construction patents decreased by 0.3%, resulting in an overall null effect on total patent applications.

1 Introduction

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 defining the modern institutional context of innovation in Canada.

2.1 The Alberta Investor Tax Credit

The AITC was a three-year program initiated by the Government of Alberta in January 2017, offering a thirty per cent tax credit to "investors who provide capital to Alberta small businesses doing research, development or commercialization of new technology, new products or new processes[1]" (Alberta Economic Development and Trade, 2017, p.1). The program was part of the *Investing in a Diversified Economy Act* , which also started the Capital Investment Tax Credit (CITC)[2]. Both programs were were phased out in 2019, and no additional funding was given to companies after March 2020 (Alberta Economic Development and Trade, 2019). The AITC was communicated as a solution to Alberta's lag in "venture capital dollars" (Alberta Economic Development and Trade, 2017, p.1) as well as a way to foster employment in the province (Zabjeck, 2016).

The program required business 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 seeking to get the tax credit. 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.

[1]Tourism, interactive media, post-production and visual effects industries were also targeted by the program.

[2]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.

In order to qualify as ”small”, businesses needed to have no more than 100 employees, pay at least 50% - 75% [3] of wages to employees working in the province, have at least C$25,000 in equity capital, and have at least 80% of assets in the province (Alberta Economic Development and Trade, 2019). Businesses which were engaged in research, development and commercialization of propietary technologies were one of the main targets of the program. 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)[4]. Mining, financial services and agricultural activities were ineligible for the receiving AITC funding.

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[5], agents, or other applicants[6]. Patent agents are external agents, commonly hired by the inventorship team, to assess the inventors on the patent application (Putnam, 2006). After sending the application, it receives its filing date[7], and the parties have a four-year period to request an examination date, where the CIPO will evaluate the invention to grant the patent. If granted, it will be valid for 20 years only within Canada (Abbes et al., 2022). The patent protects the invention from being used, made, or sold by

[3]Depending if the company was an exporter or non-exporter, respectively.

[4]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)

[5]In most cases, inventors also hold legal ownership of the patent, however, see Alam et al. (2022) and Beaudry and Schiffauerova (2011) for relevant discussions of foreign ownership of Canadian inventionships.

[6]These applicants would fall under the category of legal representatives under the *Patent Act* of Canada, which are heirs, executors, administrators of the estate, or any other actor who acts on behalf of the inventor in the patent application (Patent Act, 1985). Multiple aplicants are relevant in the case of a company which hires employees to work on patent applications.

[7]According to Canadian Intellectual Property Office (2021), incomplete applications will be returned to the parties for reapplication with a two month grace period. Applications which are not sent back by the parties are considered abandoned.

others without the inventor's permission.

The Canadian legal intellectual property framework, which provides such protections, has aligned with the American system, partly in response to the North American Free Trade Agreement (NAFTA), which required member countries to adopt harmonized intellectual property systems (Putnam, 2006). Nevertheless, a key difference between the Canadian and the American framework is that the former is much less focused on patent and copyright quality. This means that intellectual property rights infringement is much more likely in Canada, and that patent applications in Canada have a simpler and faster application process relative to the United States (Vaver, 2006).

Canada also 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 to classify patents in a standardized way - the International Patent Classification (IPC). There are 8 patent classes, which represent broad categories of inventions; within each class, there are subclasses and groups[8]. These are: 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 (World Intellectual Property Organization, 2024). The human necessities class is particularly broad, as it includes inventions related to food, clothing, medicine, among others.

The role of international treaties also respond 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 et al., 2006). Further, Canadian firms have been shown to be 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.

[8] A patent may be mapped to more than one IPC section.

2.3 The Scientific Research and Experimental Development Credits

Canada has been characterized as one of the most generous jurisdictions for R&D credits (McKenzie, 2008) as well as a pioneer in their design (Mansfield & Switzer, 1985b). According to the Canada Revenue Agency (2023), Canadian firms could deduct 100% of current research expenditures as early as 1941[9]. 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 after an amendment to the *Income Tax Act*. The tax credit has been place since then, with complex rules and regulations that have been updated over the years (Canada Revenue Agency, 2015).

Canada is unique in that most provinces offer additional incentives. The Provincial SR&ED tax credits are similar to the federal SR&ED tax credit, but they are administered by the provinces as a top-up (Warda, 2000). The provincial programs started being implemented in the 1980s, and by the early 2000s, most province's had adopted them (McKenzie, 2005; Warda, 1998). Alberta implemented the program in 2009 (Brouillete, 2013).

Given the well documented effects of these policies on R&D expenditures (Agrawal et al., 2020; Becker, 2015; Mansfield & Switzer, 1985a), it is sensible to believe that policy efforts like these have an ongoing impact on innovation. It is crucial to consider time trends to control for federal policy changes in any type of policy evaluation of other fiscal incentives like the AITC. Further, since the provincial programs are frequently reformed (McKenzie, 2005), provincial SR&ED tax credits pose threats to the identification of any other policy effect. The fact that Alberta imposed an SR&ED tax credit in 2009 could pose a threat to the identification of the AITC's effect on innovation in a quasi-experimental setting, which makes the use of event study regressions critical to validate results from a difference-in-differences approach.

[9]Mansfield and Switzer (1985b) contradicts the Canada Revenue Agency's official account, stating that it was only since 1961 that the federal government effectively allowed companies to fully deduct capital and current research expenditure from federal taxable income.

3 Empirical Approach

3.1 Data

I employ a novel administrative dataset from the Canadian Intellectual Property Office, the IP Horizons Patent Researcher Datasets. The data identify patents in Canada from 1860 to 2023, with information on when the application for the patent was filed and granted as well as the parties involved in the application. Parties can be identified 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 January 2001 to June 2021, based on the application filing date. This period corresponds to the modern Canadian intellectual property institutional context, as reviewed on Section 2. Further, limiting to a period smaller than twenty years reduces the possibility of double counting patent renewal applications. I assign patents to provinces based on where the majority of parties involved in a patent application report their location[10]. I only include the first two quarters of 2021 the last two quarters present an unusual downward trend for all provinces in late 2021, suggesting patent applications are yet to be updated. Further, I drop Newfoundland and Labrador, Prince Edward Island, Yukon and Nunavut due to missing observations on most explanatory variables.

The explained variable of interest is the count of patent applications. Further, to allow for heterogeneity in treatment, I separate patents by their International Patent Classification (IPC) section. I then consider the count of patent applications for each IPC section as separate explained variables for some models.

For my explanatory variables, I extract province-level data at the monthly frequency from Statistics Canada and later aggregate quarterly. These include data from the Labour Force Survey (LFS), such as labour force characteristics, employment wages, among others. Further, 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

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

reported by Innovation, Science and Economic Development Canada (2024) (2024) and the number of foreign parties involved in patent applications, which I obtain from the IP Horizons data. I aggregate data at the quarterly level by summing all variables except the consumer and new housing indices, for which I take arithmetic averages. Table 1 presents descriptive statistics for patents and all explanatory variables.

Table 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 Newfoundland and Labrador, Prince Edward Island, Yukon and Nunavut.

3.2 Empirical Strategy

The AITC, as an investor tax credit, did not directly affect innovation inputs such as R&D expenditures. However, since it directly provided cheaper financing for innovative firms, it may have affected innovation output in the form of patent applications. To estimate the effect of the AITC on patent applications, I implement a two-way fixed effects (TWFE) difference-in-differences (DD) design, where I define treatment and control groups based on the period the program was passed, which was 2017Q1 (January 2017) (Alberta Economic Development and

Trade, 2017). While the first investment elegibility date was in 2016Q2 (April 2016), investors could only start funding businesses starting 2017Q1, hence any effect on patent applications would be observed after this period. 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 I believe the AITC affected Albertan patent applications. The DD design is implemented in a regression framework, according to the general specification below.

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

where P_{it} is the explained variable; in most specifications, P_{it} is the number of patents filed 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 along with the addition of one to correct for provinces with small amounts of patent applications on some periods. The logarithm will aid give coefficients in the right hand side a percent interpretation. 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 average treatment effect of the AITC on the explained variable. $\mathbf{x}_{it}$ 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 stochastic error term, which varies between provinces and periods. I cluster standard errors at the province and period level, as the variance of the error term may be correlated both spatially and temporally.

Tables 2 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.

The key identifying assumption of the DD design is that, absent the AITC intervention, the trend of patent applications in Alberta would follow a similar pattern to that in control

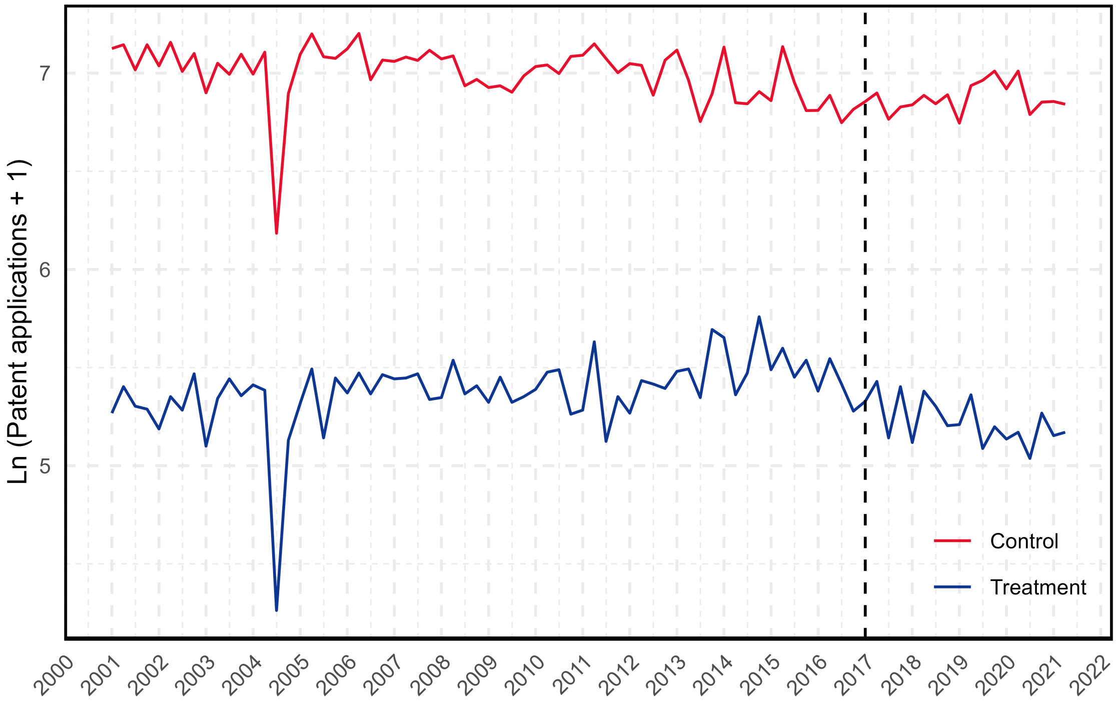
Table 2: Differences in means between treated and control provinces in province-quarter panel

Treatment		Pre	Post
Control	Ln +1 Patent applications	4.119	4.060
	Ln +1 Interested parties	5.674	5.459
	Ln +1 Inventors	300.121	295.524
	Ln +1 Applicants	157.223	140.984
	Ln +1 Owners	321.632	151.159
	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	319.453	378.444
	Ln +1 Applicants	219.875	189.722
	Ln +1 Owners	372.688	205.389
	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 Newfoundland and Labrador, Prince Edward Island, Yukon and Nunavut. The treatment group is Alberta, and the control group is made from all remaining provinces. Post-intervention periods are those after April 2016 (2016Q2).

provinces. Figure 1 shows the quarterly time series of patent applications between Alberta and control provinces from 2001Q1 to 2021Q2. This visual representation of the trends shows that Alberta's patent applications follow a similar pattern to control provinces before the intervention, however, some deviations are present before 2016Q2.

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 is made from all remaining provinces except NL, PE, YT and NU.

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 $\hat{\beta}$.

$$\ln(P_{it} + 1) = \theta_i + \tau_t + \beta_t(t \cdot A_t) + \mathbf{x}_{it}^{'}\gamma + u_{it} \tag{2}$$

$\theta_i, \tau_t, \mathbf{x}_{it}, \gamma$ and u_{it} represent the same as in Equation 1. t is a set of binary variables for each of the periods for which there is data available, with the reference level set to one period before the AITC program start (2016Q4). A_t is a binary variable equal to unity if the observation is mapped to Alberta and zero otherwise. $t \cdot A_t$ is the interaction term between these two variables, and 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 their 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 interaction terms 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 average treatment effect of the AITC on patent applications. In section 4, I justify the causal identification of the AITC effect by showing that the interaction terms before the intervention are not statistically significant. Further, I use event study regressions in the form of 2 to examine the effectiveness of the AITC by looking at post-treatment interaction terms, which should show statistically significant differences if the AITC affected Albertan patent applications.

3.3 Patent parties and province-month panel

I perform two main robustness checks on DD and event study analyses to ensure the validity of my results. First, to the extent that results may be driven by my 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].) to understand the effect of the AITC on the innovative capacity of different groups. Table 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. This panel allows for a more granular analysis of the effects of the AITC on patent applications, however, it is susceptible to noise due to the smaller number of observations, especially for the event study regressions. I present descriptive statistics of the monthly data in 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 3 presents results 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 included to account for factors which 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 in all the province's patent applications is also included, to control for foreign influences. Specification (3) considers additional controls, which are included in case that the previous ones did not account for differences in trends due to reasons other than economy, or that economic activity is not well captured by standard economic variables in Specification (2).

The DD estimate for the effect of the AITC intervention is the coefficient on Treatment ×Post, showing that the intervention led to an -9.9% to +1.1% change in Albertan patent applications. The baseline and additional controls specifications show a negative effect, while the other specification show a positive one. However, none of these are statistically significant. Standard errors for this coefficient on all three specifications are small compared to those of the controls, showing that $\hat{\beta}$ is estimated with a fairly good level of precision. This implies that it is the small magnitude of $\hat{\beta}$ which drives the low *p*-value of the hypothesis test, leading to the preliminary conclusion that the AITC intervention had no effect on innovation in the studied period.

I display the results of the event study regressions in Figure 5, which plots the $\hat{\beta}_t$ interaction coefficients in 2 with the same controls as the specifications in Table 3. For specifications (2) annd (3) there is no significant difference in patent applications between treatment control provinces for most periods before the intervention. This supports the key identifying assumption of the DD design, supporting causal evidence of a null effect as identified above by the DD estimates.

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,

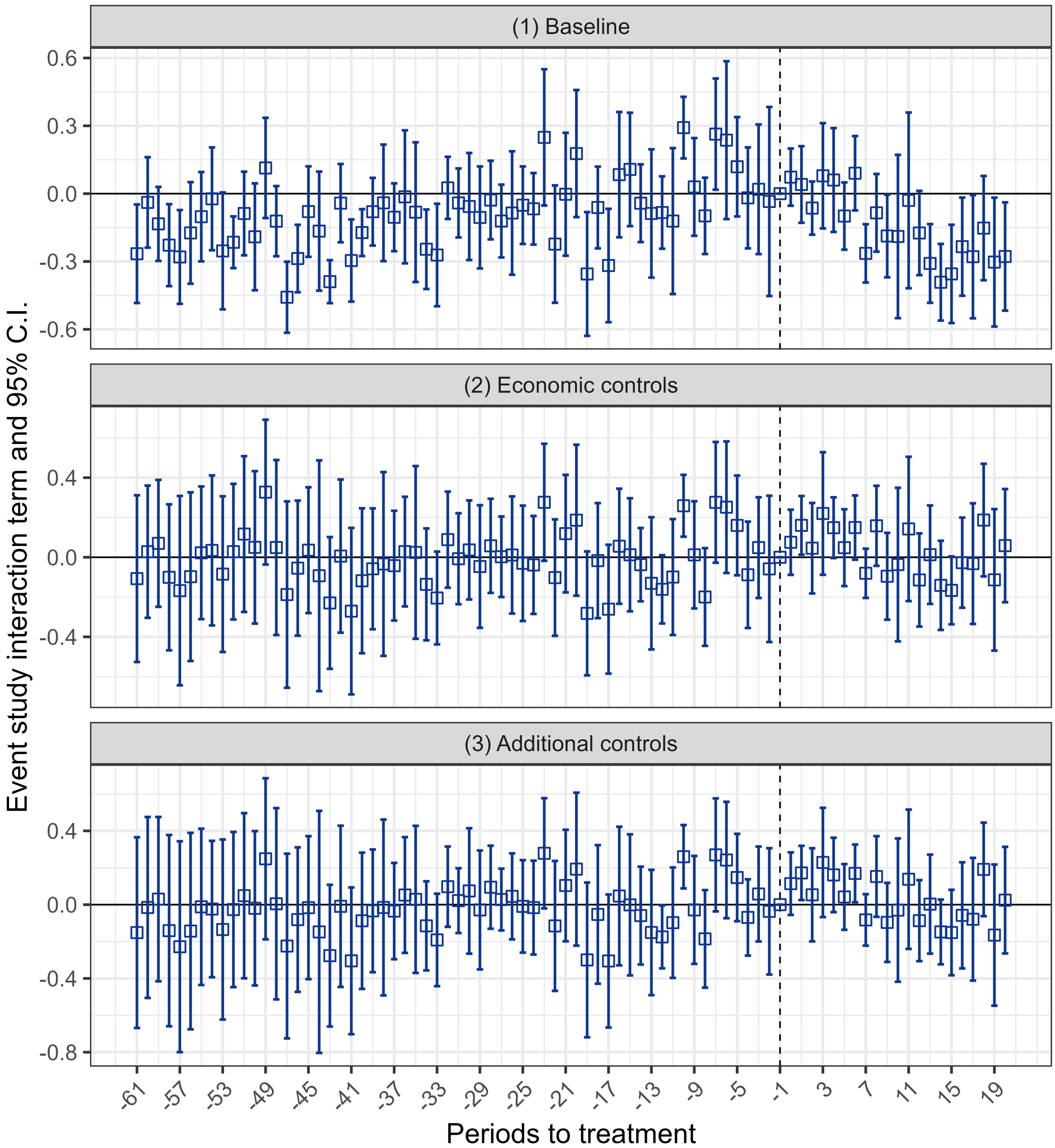
Table 3: Difference-in-differences specifications for quarterly patent applications

	(1)	(2)	(3)
Treatment x Post	-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. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

in all specifications, 2014Q1 (-10 periods to treatment) presents a statistically significant difference in patent applications between the treatment and control groups. This can be due to random noise or to a temporary real effect. Since it is only one period, it does not greatly threaten the causal identification of $\hat{\beta}$.

Figure 2: Event study plot 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 (first expense eligibility date) in April 2016, 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 3.

Regarding the effect of the policy itself, results point toward an overall null effect in the event study plots as well. While there is a small positive effect in 2017Q3, the effect is not present in the following quarters. There is also no evidence of a negative effect of the policy on patent applications, which was the the preliminary finding in Figure 1.

4.2 Patents by IPC section

In Table 4.2, I present the results of estimating Equation 1 allowing for heterogeneity by IPC patent section and including the controls of Specification (3) in Table 3. The results show that the AITC intervention had a null effect on most of the IPC sections except A and E, corresponding to human necessities and fixed constructions. The effect on section A is positive while on section E it is negative. The two coefficients are of similar magnitude (between 40.9% to 57.7% in absolute value), thus justifying the null effect on total patent applications.

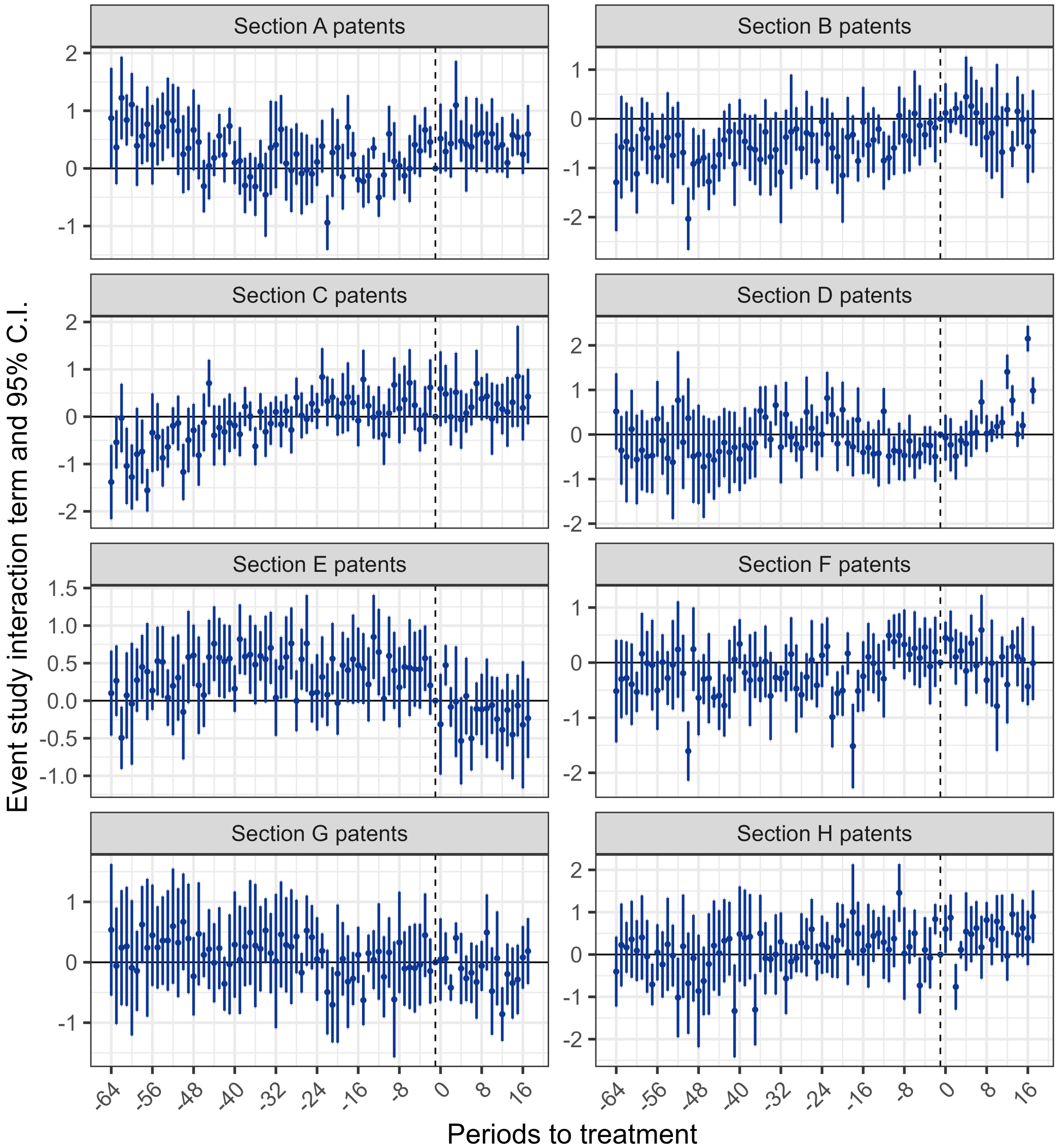
Table 4: Difference-in-differences results for quarterly patent applications by IPC section

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DD	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 3, 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, H: Electricity. Patents with multiple sections are not included. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

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. The event study regressions in Figure 3 provide additional insight about the intervention's effect on patent applications by IPC section. The figure displays the same coefficients and confidence intervals as those of in Figure 5 now separating by IPC section and restricting to the additional controls specification.

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 (first expense eligibility date) in April 2016, with the reference level being the quarter before the intervention. Controls are the same as those in Specification (3) in Table 3.

Human necessity (A) patents, which include agriculture, medicine and apparel related inventions, showed several periods with significant differences relative to the reference period, with differences ranging from 9% to 59%. However, pre-intervention coefficients are less stable for this section, potentially due to its broad definition.

Fixed constructions (E) patents, which include patents related to buildings, roads, and bridges show a significant decrease in most quarters after the intervention. It is unclear why fixed constructions patents would not be affected by the policy, given its broad definition. However, once again the pre-policy trend is less stable for this section, which may be driving the negative effect in the post-policy period.

Other notable results which were not picked up by the DD specification are the Section D patents, which include patents related to textiles and paper. While less stable than other sections in the post-policy trend, these patents show the most important increases, the highest being 215% more patent applications 17 quarters after the intervention. The DD may not capture this effect due to increases being present next to quarters without increases.

In general, the event study plots show much less stability in pretrends than with total patents, which difficults the interpretation of the results. However, the event study plots show how section A patents saw positive differences when section E patents saw negative differences, which may be driving the null effect on total patents. Further, Section D patents show a positive effect which is not captured by the DD specification, and may also be offset by the section E negative effect.

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 and the controls in Specification (3) of Table 3. 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 having the number of interested parties as an explained variable proxies for both the number of patents in a province but also the size of the application team. This makes the use of the natural logarithm transformation crucial for a better interpretation of the DD estimate.

Event study plots show that the effect is null for all post-policy periods for total parties, applicants and owners. Inventor parties see a positive difference between the treatment and control groups in the first two quarters after the intervention, which disappears in the following quarters. This is consistent with patent specifications in the previous subsections. Pre-policy trends are much less stable for parties comparetd to patents. Between 52 to 36 quarters before the intervention, the treatment and control groups diverge significantly for patent parties. Because this difference disappears in the following quarters, this difference does not pose a substantial threat to causal identification. Overall, patent application counts behave similarly to parties within patent applications in both the DD and event study regressions. This suggests that my mapping of patents to provinces is not driving the effect to zero.

Appendix C reproduces the DD specifications and event study regression using the province-month panel. DD specifications also show a null effect of the AITC intervention on the log of patent applications, considering all three specifications in Table 3 (baseline, economic and additional controls). The additional precision does not change my results, which further disproves the possibility of an underpowered statistical analysis driving the null effect with the province-quarter panel. The event study plot shows a similar post-intervention pattern, showing a small positive effect shortly after the first month of elegibility, which is not present in the following months. The finer granularity of the data allows to identify small positive effects in the last months of 2020, which disappear in 2021. The pre-policy trend is less stable than the quarter panel, notably around 2004. Results are similar for the IPC section disaggregations, yet with considerably more instability in the pre-policy trend.

5 Conclusions

6 Acknowledgements

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A Appendix: Descriptive statistics for province-month panel

Table A.5: Descriptive statistics for variables in the province-month panel

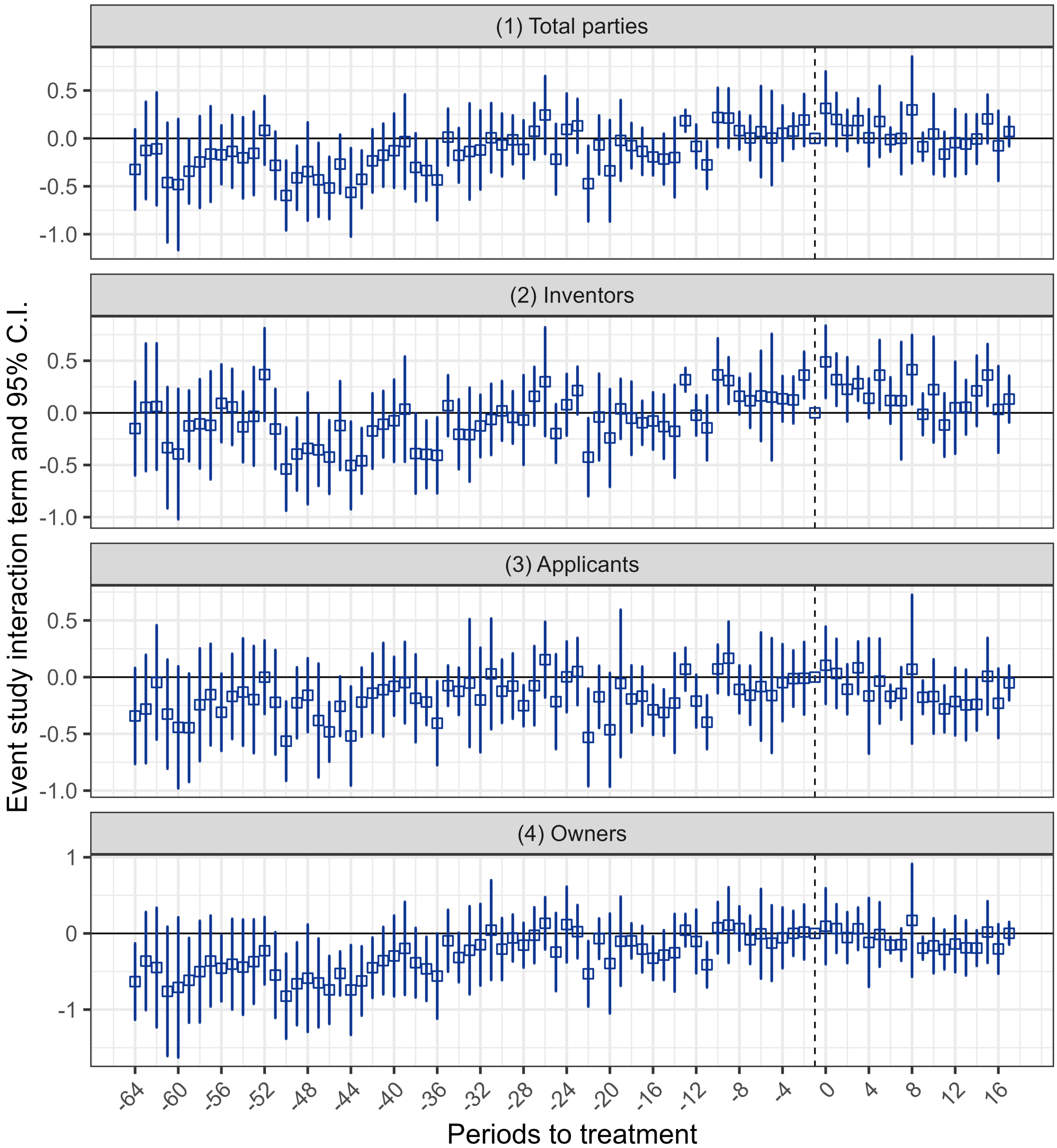
	Mean	SD	Min	Median	Max
Ln +1 Patent applications	3.187	1.400	0.000	3.178	5.714
Ln Full-time employment	6.927	1.034	5.614	6.733	8.722
Ln Median wage	2.945	0.193	2.487	2.956	3.411
CPI	118.994	12.717	93.400	119.000	148.900
Ln +1 Business insolvencies	3.327	1.388	0.000	3.135	5.974
Ln Intl. exports	14.709	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 Newfoundland and Labrador, Prince Edward Island, Yukon and Nunavut.

B Appendix: Patent parties models

C Appendix: Province-month panel results

Figure 4: 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 (first expense eligibility date) in April 2016, 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 3.

Table A.6: 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 Newfoundland and Labrador, Prince Edward Island, Yukon and Nunavut. Treatment group is Alberta, and control group is all remaining provinces. Post-intervention periods are those after April 2016.

Table B.7: Difference-in-differences specifications for quarterly patent applications

	(1)	(2)	(3)	(4)
DD	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 3, not shown for brevity and fixed effects for provinces and quarters. Clustered standard errors at the province and quarter level shown in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table C.8: DD specifications for monthly patent applications

	(1)	(2)	(3)
Treatment x Post	-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

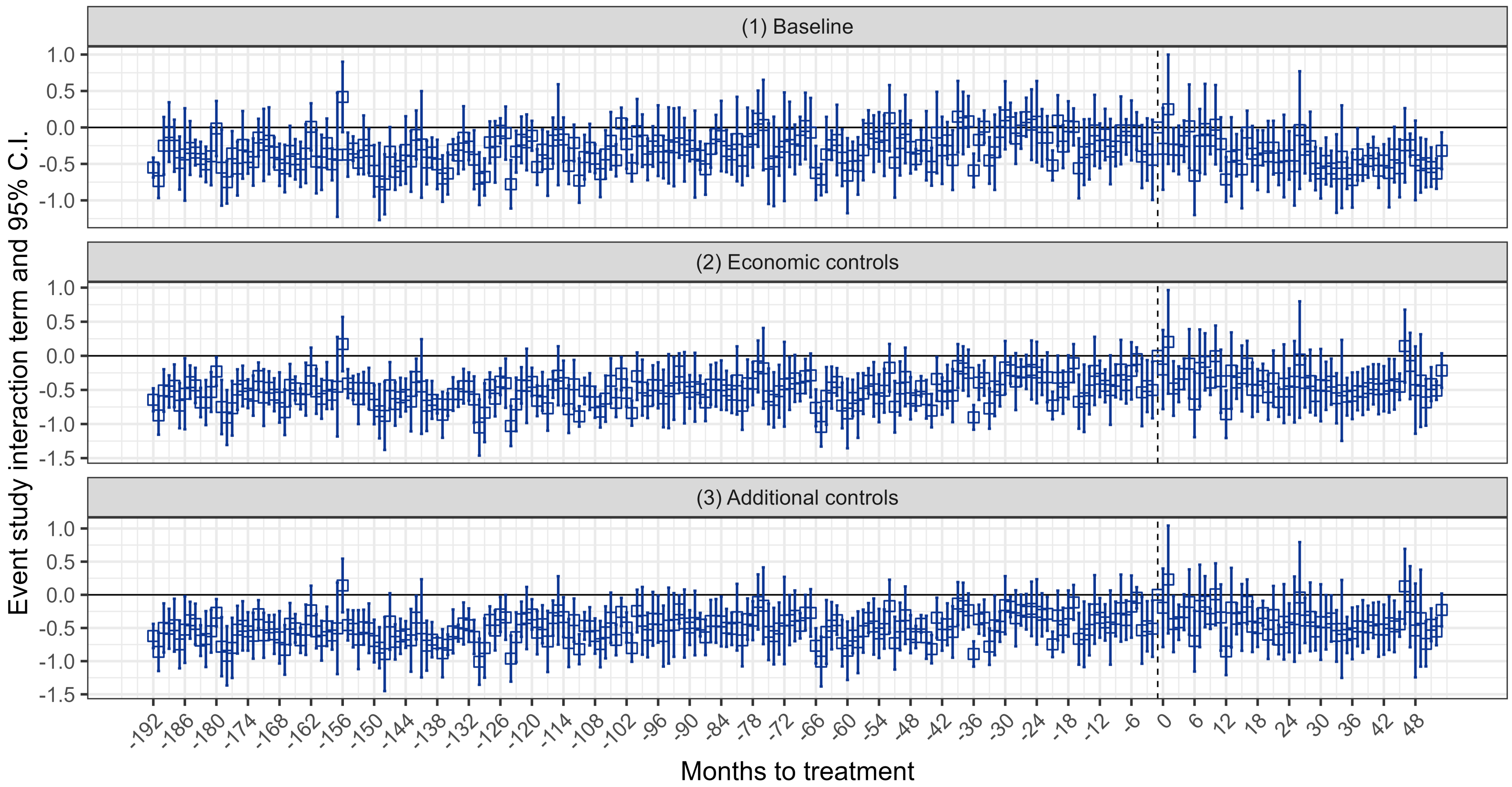
Notes: Clustered standard errors at the province and monthly level shown in parentheses. Specifications include fixed effects for provinces and months and the controls for their quarterly counterpart in Table 3. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table C.9: Difference-in-differences results for monthly patent applications by IPC section

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment x Post	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

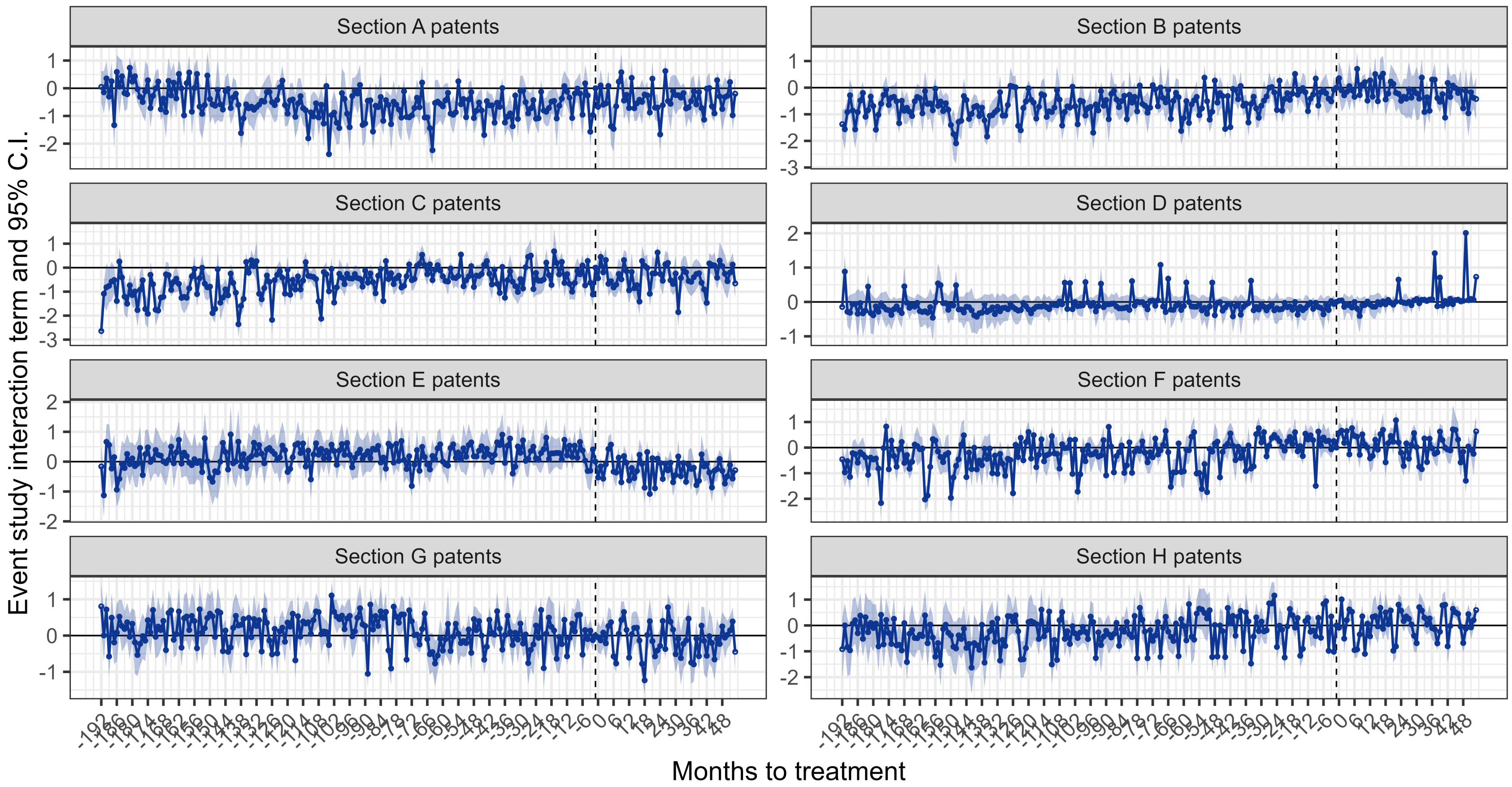
Notes: Sections of the IPC are A: Human Necessities, B: Performing Operations; Transporting, C: Chemistry; Metallurgy, D: Textiles; Paper, E: Fixed Constructions, F: Mechanical Engineering; G: Physics, H: Electricity. Patents with multiple sections are not included. All specifications include controls in Specification (3) of Table C.8, not shown for brevity and fixed effects for provinces and monthy. Clustered standard errors at the province and month level shown in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Figure 5: 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 (first expense eligibility date) in April 2016, 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.8.

Figure 6: 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, separating 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 (first expense eligibility date) in April 2016, with the reference level being the quarter before the intervention. Controls are the same as those in Specification (3) in Table 3.