

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

Daniel Sánchez Pazmiño

ECON899 MA Paper

Simon Fraser University

April 2024

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. I investigate the impact of the Alberta Investor Tax Credit (AITC) in Canada, which offered a tax credit for investments in innovative businesses. Exploiting variation from patent application counts, I find that the AITC had an overall null effect on patent applications, increasing applications for human necessity and textile inventions but decreasing them for fixed construction inventions.

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 & 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 et al., 2019). An extensive literature 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 expenditure¹ 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. 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 fiscal incentives, 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 Albertan firms. I estimate the impact of the AITC on patent applications using a two-way fixed effects difference-in-differences design, validating causal identification through event study

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

specifications. I map patent applications to provinces using a novel administrative dataset from the Canadian Intellectual Property Office (CIPO), using the reported locations of parties from patent applications. My results show that the AITC had an overall null effect on Alberta patent applications. Separating by International Patent Classification (IPC) sections, I find that the intervention increased human necessity and textile invention patents, yet the effect was offset by a decrease in fixed construction patents.

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 (Artz et al., 2010; Nordhaus, 1969; Pavitt, 1985; Trajtenberg, 1990). Patents have been used to estimate the knowledge spillover generated by the innovation process, specifically using patent citations in patent applications (Jaffe et al., 1993; Trajtenberg, 1990). While using patent data has been shown to have limitations (Lanjouw et al., 1998), others have been shown that patents move together with other innovation products (Lanjouw & Schankerman, 2004).

My findings make three main 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 (Lyon, 1989; Pereira, 1994; Slattery & Zidar, 2020). This owes to the fact that invest 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 policy by governments. The literature should incorporate nontraditional fiscal incentives to understand how they affect innovation outcomes.

Second, to my knowledge, no work has been done in evaluating 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 et al., 2019). Using patent applications as the explained variable allows me to capture innovation which is 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. Exploiting variation in patent applications allows me to avoid this issue altogether.

Third, I extend the literature on Canadian fiscal policy, which has given 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 et al., 2020; Bernstein, 1986; Bérubé & Mohnen, 2009; Czarnitzki et al., 2011; Mansfield & Switzer, 1985b). 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 defining the applicable institutional context, specifically regarding potential threats to identification.

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 percent tax 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)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 (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) relative to other large Canadian provinces, as well as a way to foster employment (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.

In order to qualify as “small”, businesses could not have more than 100 employees. Ad-

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

³The 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.

ditionally, they were required to pay at least 50%-75% of wages to employees working in the province⁴, 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 proprietary 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)⁵. 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, owners⁶, agents, or other applicants⁷. 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 receive a filing date⁸, and the parties 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 et al., 2022). The patent protects the invention from being used,

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

⁵The *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).

⁶In 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 inventions.

⁷These 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 applicants are relevant in the case of a company which hires employees to work on patent applications.

⁸According 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.

made, or sold by others without the inventor's permission. When expired, a patent can be renewed through a renewal application.

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). There are 8 patent classes, which represent broad categories of inventions; within each class, there are subclasses and groups⁹. 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.

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 1941¹⁰. 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,

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

¹⁰Mansfield 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.

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, with complex rules and regulations that have been amended 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 the provinces administer them (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 SR&ED changes. Further, since the provincial programs are frequently reformed (McKenzie, 2005), provincial SR&ED tax credits pose threats to causal identification. 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.

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 with the application filing date and all parties involved. 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's filing date. This period corresponds to the modern Canadian institutional context, as reviewed on Section 2, where most provinces had already implemented their SR&ED programs. I assign patents to provinces based on

where the majority of parties involved in a patent application report their location¹¹. 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 updated¹². Further, I drop Newfoundland and Labrador (NL), Prince Edward Island (PE), Yukon (YU) and Nunavut (NU) due to missing observations on explanatory variables.

The main explained variable is patent application count. Further, I separate patents by their International Patent Classification (IPC) section. I patent applications by 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 aggregate quarterly. These include data from the Labour Force Survey (LFS), such as labour force characteristics, employment wages, among others (2024a, 2024b, 2024j, 2024k). Further, I also consider the consumer price index (2024e), international merchandise exports and imports (2024h), retail, wholesale and manufacturing trade sales (2023, 2024c, 2024d), food services receipts (2024g), the new housing price index (2024f) and electric power generation (2008, 2024i). 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 data at the quarterly level by summing all variables except the consumer and new housing indices, which I average over months. Table 1 presents descriptive statistics for total patent counts and all explanatory variables.

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-

¹¹Patent applications without information of party provinces or with an equal number of interested parties from two provinces are dropped from the sample.

¹²Canadian Intellectual Property Office (2023) states that the IP Horizons datasets are updated with 18 month lags. While 2021 data should be included as of this date, it is subject to revision in the next update of the dataset in December 2024.

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.

in-differences (DD) design, where I define treatment and control groups based on when the program was passed (2017Q1) (Alberta Economic Development and Trade, 2017). While the first investment eligibility date was before 2017Q1, 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.

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

where P_{it} is patent applications in a province i and period t . θ_i and θ_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 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 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 correlated across variances and time periods.

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 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 $\hat{\beta}$.

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

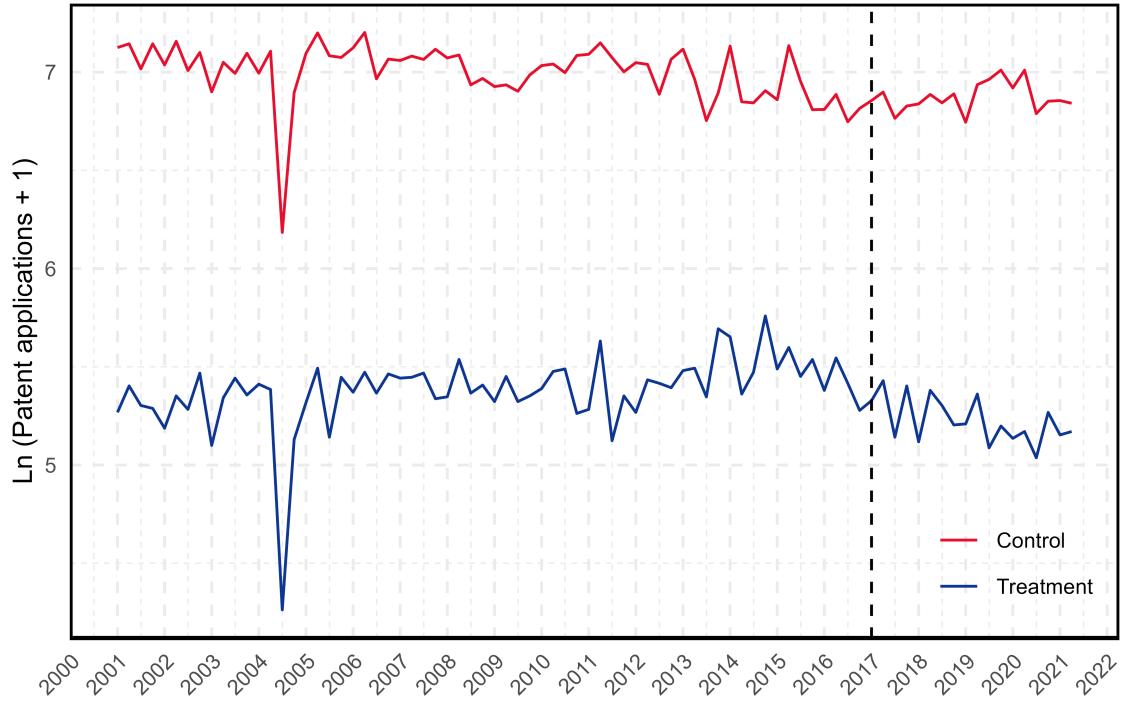
$\theta_i, \tau_t, \mathbf{x}_{it}, \gamma$ and u_{it} represent the same as in Equation 1. τ_t has its reference level set to one period before the AITC program start (2016Q4). A_t is a binary variable equal to unity for Alberta observations and zero otherwise. $\tau_t \cdot A_t$ is the interaction 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,

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	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 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).

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.

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 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 applicants¹³). 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. I present descriptive statistics of the monthly data in Appendix A.

4 Results

4.1 Patent applications

Table 3 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 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 \times 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.

¹³I do not consider agents as a separate category due to them being hired professionals, which is not informative about the patent application team.

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

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) and (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, 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 $\hat{\beta}$.

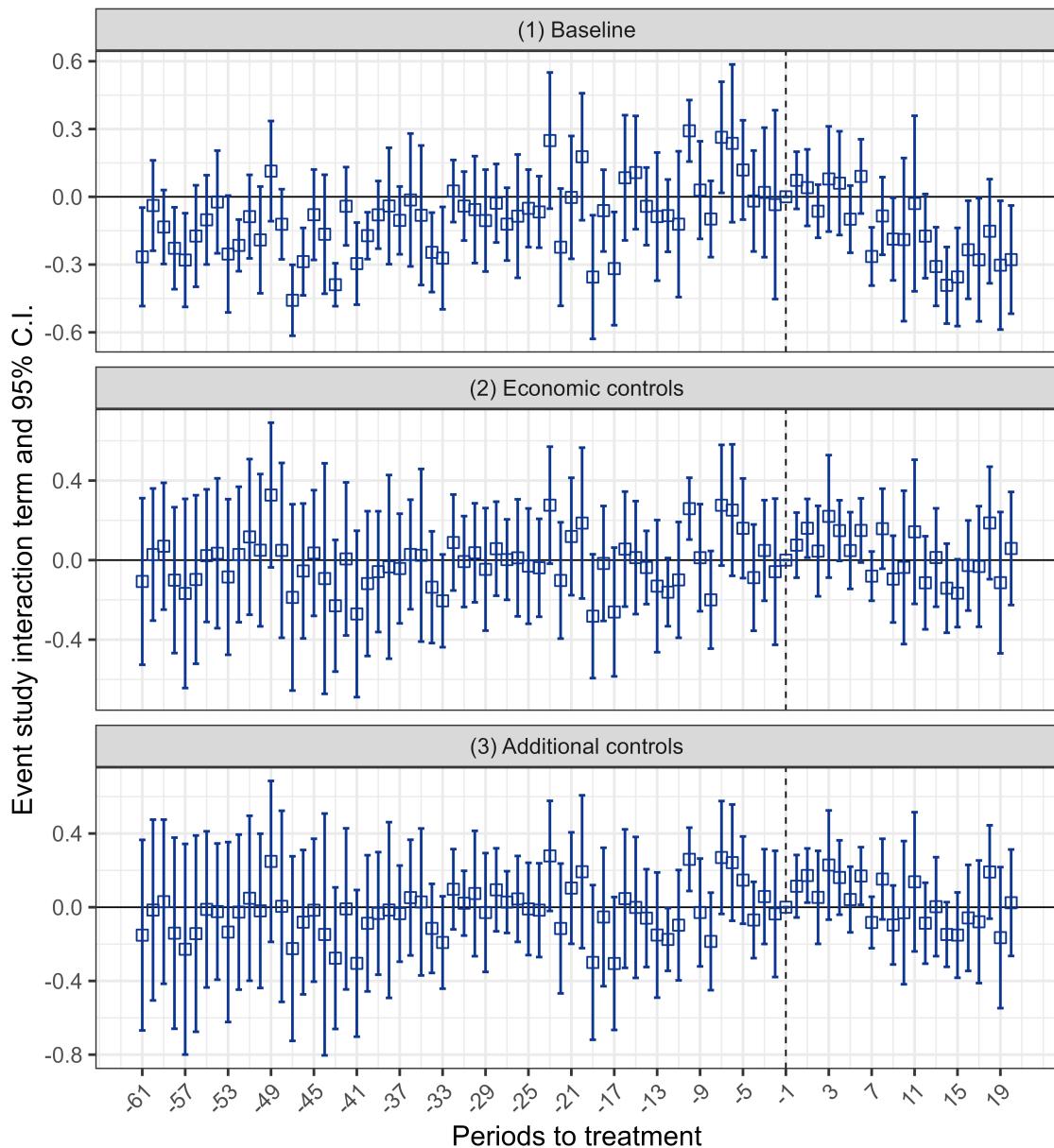
Regarding the effect of the policy itself, results point toward an overall null effect in the event study plots as well. While there is a small positive effect in 2017Q3, the effect is not present in the following quarters. There is also no evidence of a negative effect of the policy on patent applications,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

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

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.

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DD	0.409*** (0.077)	0.329 (0.215)	0.068 (0.186)	0.334** (0.138)	-0.577*** (0.062)	0.164 (0.107)	-0.138 (0.193)	0.229 (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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

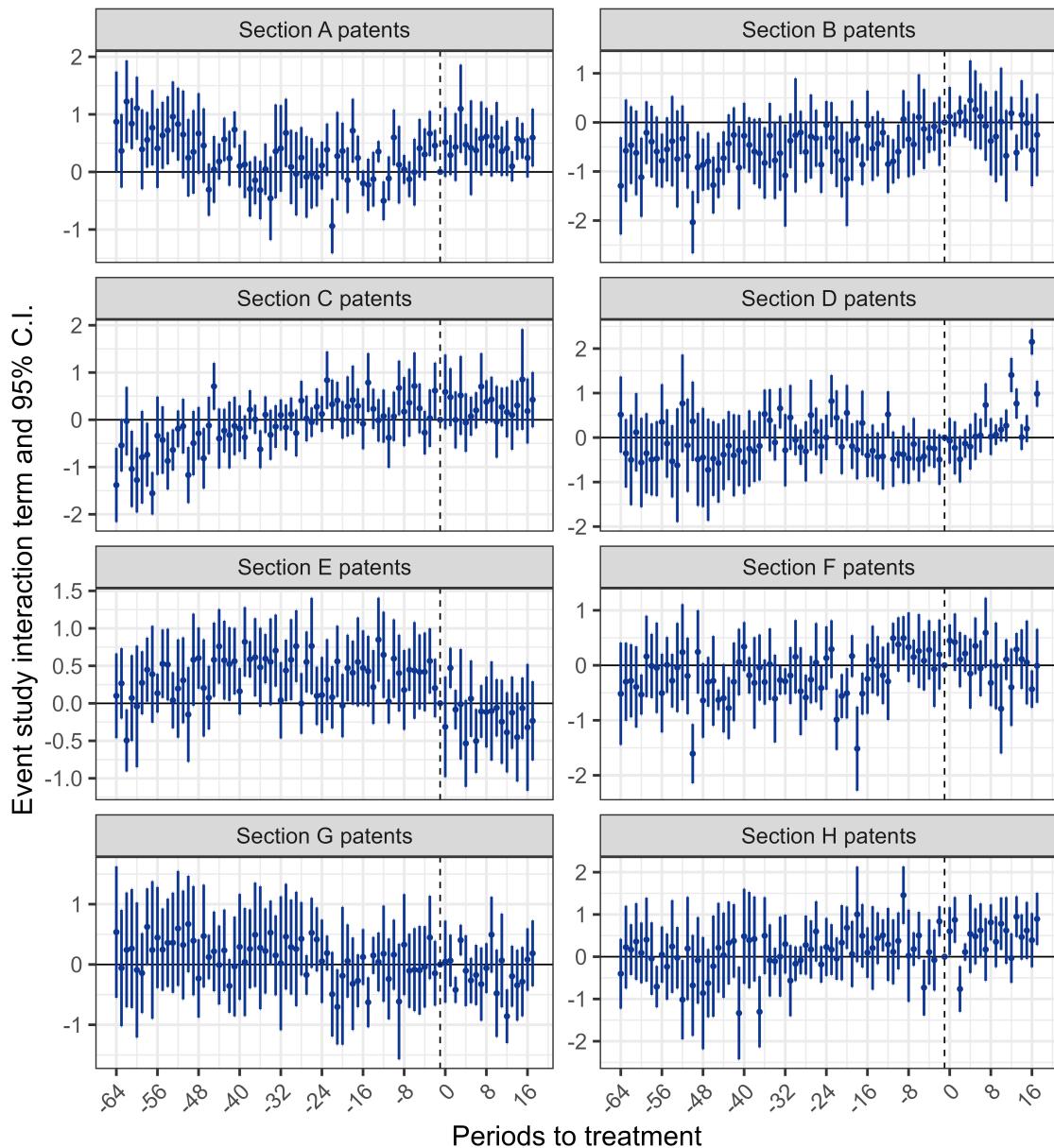
controls specification.

Human necessity (A) patents, which include agriculture, medicine and apparel-related inventions, showed several post-intervention 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. 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.

A notable result, which was not picked up by the DD framework, is the effect on Section D patents. Section D includes inventions 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. In the pre-policy periods, the differences are not statistically significant, which implies that the increases in textile and paper applications can be attributed to the AITC. 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 patent applications, which complicates interpretability. However, the event study plots show how section A patents saw positive differences when section E patents saw negative differ-

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.

ences, 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. All models use 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 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 the number of parties is an inflated indicator of innovation.

Event study plots show that the effect is null for all post-policy periods for total parties, applicants and owners. Pre-policy trends are much less stable for parties compared to patent applications, particularly in 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 causal identification. Overall, patent application counts behave similarly to parties within patent applications in both the DD and event study regressions. This means that my mapping of patents to provinces does not drive my results.

Appendix C reproduces the DD specifications and event study regression using the province-month panel. Monthly DD specifications 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 same is true for IPC sections. 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 be-

ing 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 less 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.

5 Conclusion

This paper estimates the impact of an investment tax credit in Canada, the Alberta Investor Tax Credit (AITC) on innovation outcomes. The AITC provided a thirty percent tax credit to investments in small businesses which undertook research, development and commercialization activities in Alberta. 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 on patent applications. I find that the AITC had a null effect on patent applications from Albertan parties. By allowing for heterogeneity in treatment effects across International Patent Classification (IPC) sections, I find evidence that the policy increased applications for textile and human necessity inventions, yet decreased applications for fixed construction inventions. These results are robust to the use of patent application parties as the explained variable, which ensure that results are not driven by my mapping of patent applications to provinces. Further, the results 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 which 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 et al., 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. First, by using patent application counts, I focus on a short-term innovation outcome, which allows me to avoid the mentioned R&D relabeling issue altogether. Similar work has focused on how R&D tax credits affect R&D expenditure, mostly finding positive effects (Becker, 2015; Guceri, 2018; Guceri & Liu, 2019; Rao, 2016). No work has been done on how intellectual property responds to fiscal incentives, which makes this the first result which accurately corrects for financial statement manipulation and the omission of non R&D innovation.

Second, I analyze an investment tax credit, an understudied policy in the relevant literature. Prior studies have typically focused on the impacts of tax credits to firms on R&D expenditure, giving little attention to alternative policy such as tax credits to investors. The literature on investment tax credits has mostly focused on their macroeconomic impacts and effects on firm outcomes (Lyon, 1989; Pereira, 1994; Slattery & Zidar, 2020), with little attention to their effects on innovation. To my knowledge, no other paper has focused how providing easier access to financing for innovative businesses affects innovation outcomes. While traditional tax credits have not had an innovation motive, the introduction of the AITC shows how governments can use tax credits to promote innovation in non-traditional ways.

Third, I extend the literature on Canadian fiscal policy, which has only studied the Scientific Research and Experimental Development (SR&ED) programs. Canada is generally known for its generous R&D tax credits through the SR&ED programs, which have motivated a large literature on their effects (Agrawal et al., 2020; Bernstein, 1986; Bérubé & Mohnen, 2009; Czarnitzki et al., 2011; Mansfield & Switzer, 1985b). However, other programs which may significantly change the innovation landscape have received no attention. 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. My inability to observe R&D at the province level due to data limitations allows for other mechanisms which can explain the null effect which do not relate to the ineffectiveness of the AITC intervention. One is the recognized possibility that patent data does not capture innovation which happens outside the patent system (Moser, 2013). It is important to validate the paper's results by examining the effectiveness of the intervention on R&D using financial statement data from small firms. By doing this, it will be possible through which mechanism the null effect is observed. In the same line, there is evidence that patent activity does not reflect innovation but rather strategic response to regulatory changes (Graham & Mowrey, 2004) and 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.

Further, while the results from my event study regressions support causal identification in the quarterly data between, the results are less conclusive for the monthly data. The existence of a predictable deviation from common trends between Alberta and the control provinces in the monthly data might involve 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. The use of a TWFE difference-in-differences estimator may be inadequate for this type of quasi-experimental setting. Future research should focus using other methods, such as matching (Caliendo & Kopeinig, 2008) and synthetic control (Abadie et al., 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 which have are fundamentally unstable across time in the institutional context, such as employment. Adequately evaluating non-traditional fiscal incentives for innovation is a crucial step in the discipline's understanding of the public sector solution to private underinvestment in innovation, and this paper provides an initial understanding of this objective.

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.

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
Treatment	Ln +1 Multiple section applications	1.918	2.034
	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
Treatment	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. The treatment group is Alberta, and the control group includes all remaining provinces. Post-intervention periods are those after April 2016.

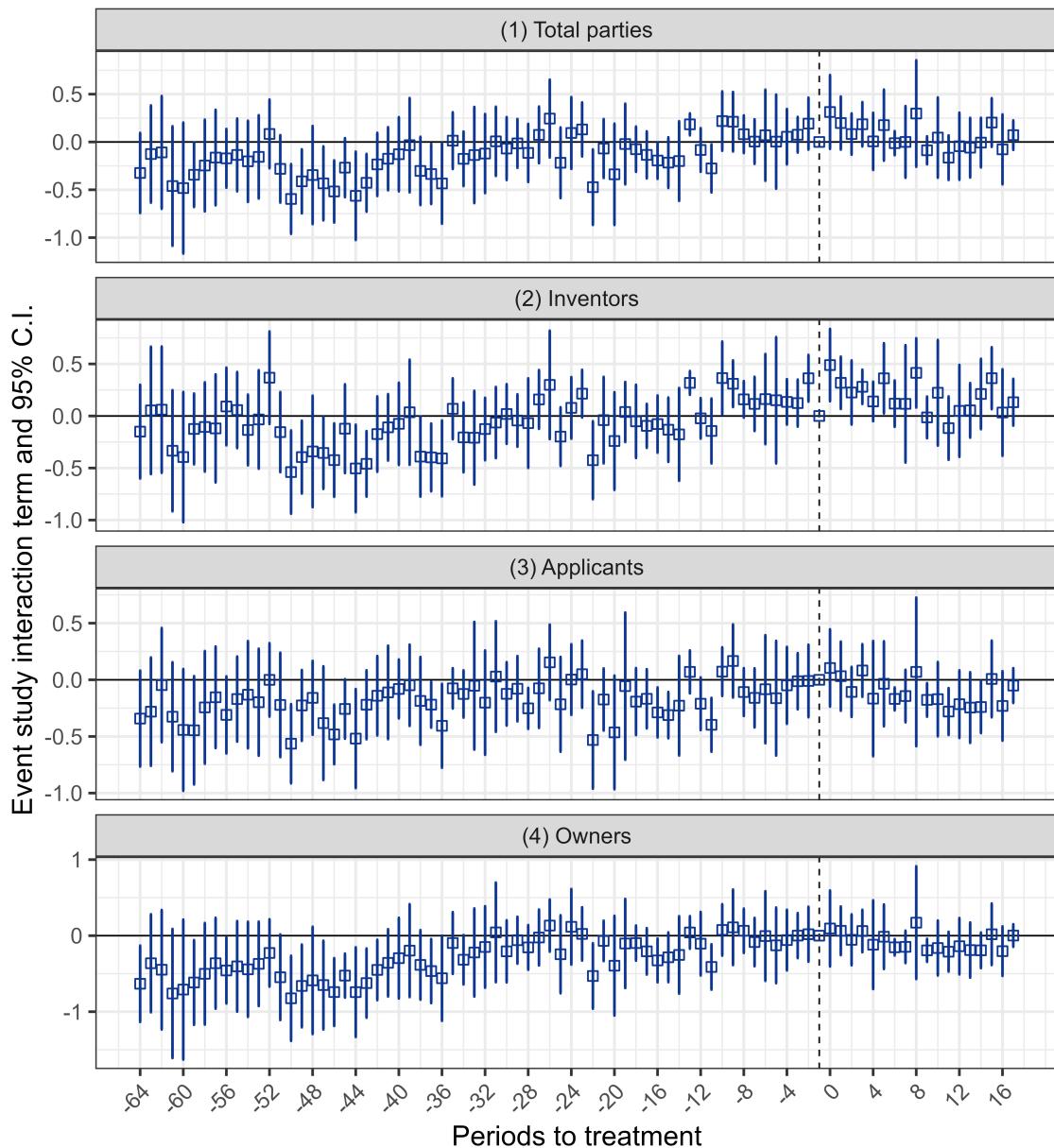
B Appendix: Patent parties models

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

	(1)	(2)	(3)	(4)
DD	0.082 (0.101)	0.149 (0.117)	0.007 (0.079)	0.012 (0.096)
Party type	Total	Inventors	Applicants	Owners
<i>N</i>	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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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.

C Appendix: Province-month panel results

Table C.8: DD specifications for monthly patent applications

	(1)	(2)	(3)
Treatment x Post	-0.092* (0.041)	0.052 (0.070)	0.040 (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 3. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

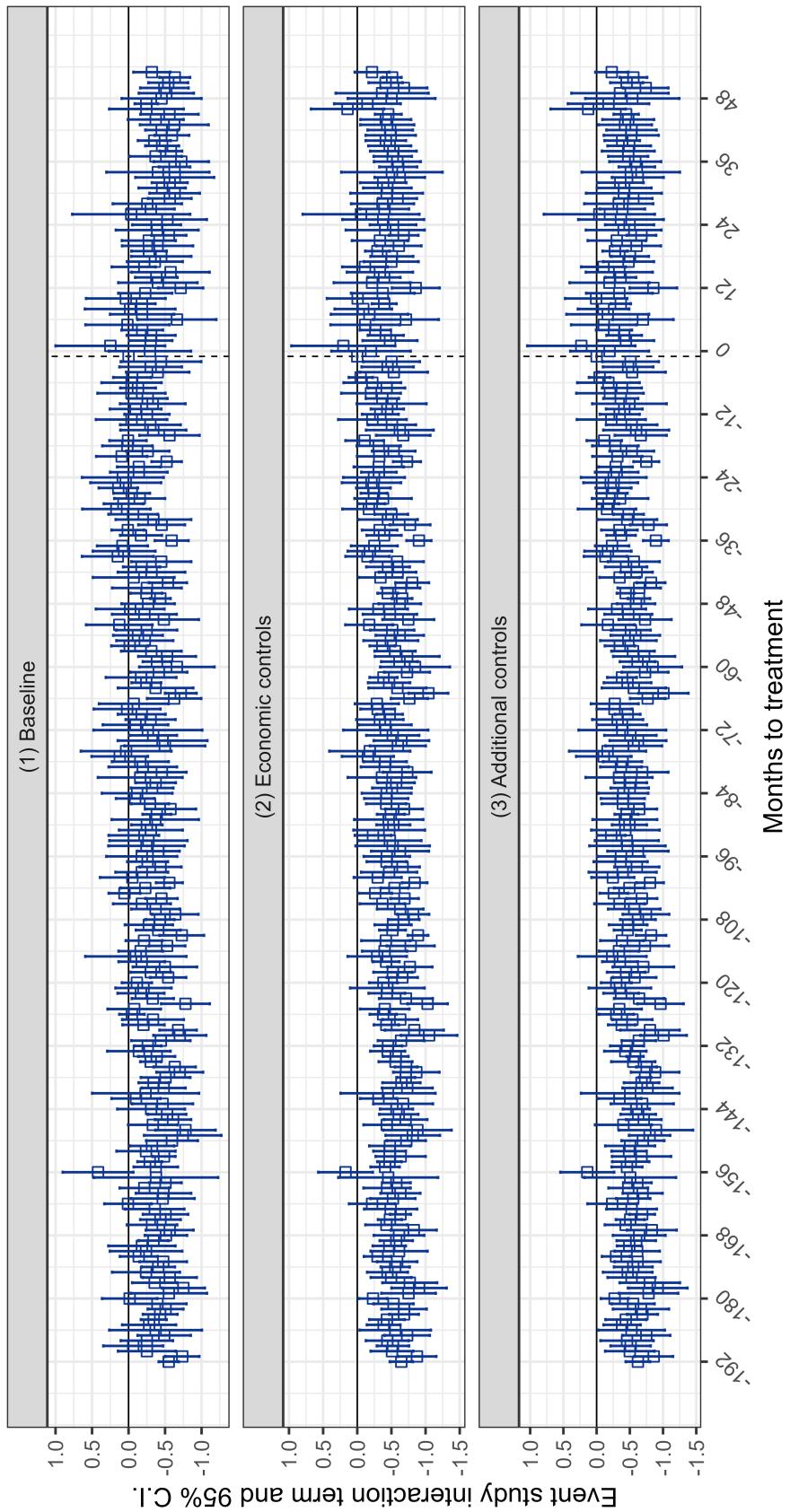
Table C.9: Difference-in-differences results for monthly patent applications by IPC section

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment x Post	0.290*** (0.063)	0.308** (0.130)	-0.013 (0.127)	0.134** (0.050)	-0.513*** (0.074)	0.220** (0.087)	-0.189 (0.107)	0.195* (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.8, not shown for brevity and fixed effects for provinces and months. Clustered standard errors at the province and month level shown in parentheses.

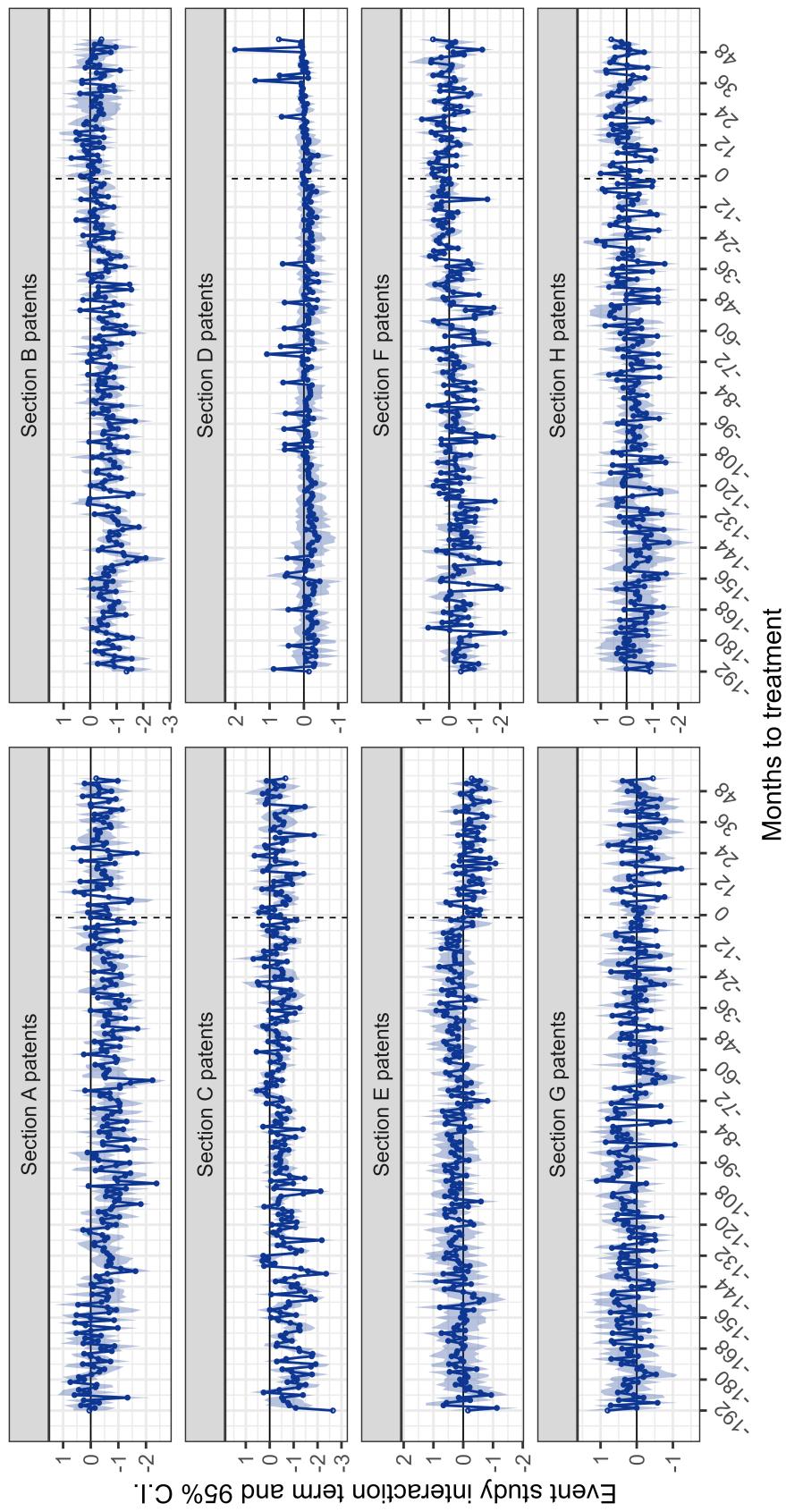
Sections of the IPC are A: Human Necessities, B: Performing Operations; Transporting, C: Chemistry; Metallurgy, D: Textiles; Paper, E: Fixed Constructions, F: Mechanical Engineering; G: Physics, H: Electricity. Patents with multiple sections are not included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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 ATTC 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.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 in January 2017, with the reference level being the quarter before the intervention. Controls are the same as those in Specification (3) in Table 3.