

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

Daniel Sánchez Pazmiño

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Simon Fraser University

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The idea that positive knowledge spillover from research efforts disincentivizes its private sector investment has led to widespread support for fiscal incentives to promote innovation. Although the literature on research and development (R&D) tax credits is extensive, alternative innovation policy has been understudied. I investigate the impact of the Alberta Investor Tax Credit (AITC) in Canada, which offered a tax credit for investments in innovative businesses. I find that the AITC did not have statistically significant impact on patent applications from Albertan parties. The results suggest that the AITC was unsuccessful in fostering innovation through intellectual property products.

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). A large body of work has emerged to study fiscal incentives for innovation, notably on research and expenditure (R&D) tax credits, yet alternative fiscal policy has received little attention. In this paper, I investigate a fiscal policy aimed to increase investment in innovative firms, the Alberta Investment Tax Credit (AITC), and its effect on patent applications.

The extensive literature on the effects of R&D tax credits has mostly found that these programs positively impact R&D 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 map patent applications to provinces using a novel administrative dataset from the Canadian Intellectual Property Office (CIPO), using the reported locations of parties

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

from patent applications. Using this mapping, I estimate the impact of the AITC on patent applications using a two-way fixed effects difference-in-differences design. My results show that after the AITC was passed, Albertan parties did not increase their patent applications relative to other provinces who did not pass similar legislation. I validate these results using an event study design, which shows that for total patent applications, most pre-intervention periods show no statistically significant differences between treated and control groups, which supports the difference-in-differences parallel trends assumption. Most post-intervention periods in the event study show that the AITC had no significant effect on patent applications, some of them displaying a marginally negative effect.

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. Separating by International Patent Classification (IPC) sections, I find that the AITC had a significant effect on human necessity, textile and fixed construction invention applications. However, I cannot reject that changes identified by models are due to random chance or to factors unrelated to the AITC, since common trends between treated and control groups do not hold.

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 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 investment tax credits are typically used to stimulate investment in capital goods, which has a fundamentally different purpose to the traditional R&D tax credits. However, modern programs such as the AITC have received significant attention from the public (Alberta Chamber of Commerce, 2023; Zabjeck, 2016), which may lead to the increased use of similar policies by governments. The literature should incorporate nontraditional fiscal incentives to understand how they affect innovation outcomes.

Second, to my knowledge, no 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 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 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 ?? 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

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.

equity capital from investors. Only investors who had paid corporate or personal taxes in the province were eligible. While the *Investing in a Diversified Economy Act* was passed in January 2017, eligible investments in VCCs and ECCs were available to be claimed as credits retroactively from April 2016 onwards.

To qualify as “small”, businesses could not have more than 100 employees. Additionally, they were required to pay at least 50%-75% of wages to employees working in 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 that 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 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 receives

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 that hires employees to work on patent applications.

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

2.3 The Scientific Research and Experimental Development Credits

Canada has been characterized as one of the most generous jurisdictions for R&D credits (McKenzie, 2008) as well as a pioneer in their design (Mansfield & Switzer, 1985b). According

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

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

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, 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 in the 1980s, and by the early 2000s, most provinces had adopted them (McKenzie, 2005; Warda, 1998). Alberta implemented the program in 2009 (Brouillette, 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, including all involved parties and the filing date received by the CIPO. Parties can be mapped

¹⁰Mansfield and Switzer (1985b) contradict 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.

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. This period corresponds to the modern Canadian institutional context, as reviewed in 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 as the other quarters present an unusual downward trend, 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.

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 NL, PE, YU and NU.

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

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.

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 it at the quarterly frequency. 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-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 in 2016, businesses only started receiving AITC funding after 2017Q1, hence any effect would only be observed then. The treatment group is Alberta, and the treatment period is composed of all periods after 2017Q1. The control group is all remaining Canadian provinces in the sample. Treated observations are those from Alberta after 2017Q1, where the AITC may have affected Albertan patent applications. The DD design is implemented in a regression framework according to Equation 1 below.

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

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

Table 2 present 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 treatment start period (2016Q4). A_t is a binary variable equal to unity for Alberta observations and zero otherwise. $\tau_t \cdot A_t$ is the interaction term between these two

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



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

variables. β_t is the associated vector of coefficients, which will show the difference between the treatment and control groups in the explained variable for all t . For these regressions, I show the values of the interaction terms in event study plots, along with 95% confidence intervals. I cluster standard errors at the province and period level.

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

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 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 |
| Treatment | Ln +1 Multiple section applications | 2.873 | 3.006 |
| | Ln +1 Patent applications | 5.380 | 5.228 |
| | Ln +1 Interested parties | 6.800 | 6.645 |
| | Ln +1 Inventors | 5.731 | 5.930 |
| | Ln +1 Applicants | 5.380 | 5.245 |
| | Ln +1 Owners | 5.886 | 5.322 |
| | Ln +1 Total population | 9.050 | 9.241 |
| | Ln +1 Section A applications | 2.714 | 2.893 |
| | Ln +1 Section B applications | 2.939 | 2.992 |
| | Ln +1 Section C applications | 2.634 | 2.626 |
| | Ln +1 Section D applications | 0.181 | 0.301 |
| | Ln +1 Section E applications | 4.076 | 3.699 |
| | Ln +1 Section F applications | 2.513 | 2.377 |
| | Ln +1 Section G applications | 3.067 | 2.844 |
| | Ln +1 Section H applications | 1.945 | 1.780 |
| | Ln +1 Multiple section applications | 4.104 | 4.096 |

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

cation (2) includes economic controls to account for factors that may affect the comparability of the treatment and control groups regarding firm activity and overall economic trends which vary across time and provinces. The number of foreign parties involved in patent applications is also included, to control for foreign influences. Specification (3) considers additional controls, which are included in case the previous ones did not account for differences in trends due to reasons other than the economy, or that economic activity is not well captured by standard economic variables in Specification (2).

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

I display the results of the event study regressions in Figure 2, which plots the $\hat{\beta}_t$ interaction 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 and control groups for most pre-intervention periods. This supports the key identifying assumption of the DD design, supporting the causal identification of $\hat{\beta}$. The baseline model does show several pre-policy periods where the treatment and control groups diverge, underscoring the importance of including controls in the model. However, in all specifications, there are particular periods for which a statistically significant difference exists. This can be due to random noise or to a temporary real effect. Since it is only one period that disappears later, I do not consider it a substantial threat to the causal identification of $\hat{\beta}$. Regarding the effect of the policy itself, results point toward an overall null effect in the event study plots as well. There are marginally negative effects on some periods, which appear next to periods with null effects. This evidence supports the null effect found in the DD specifications (2) and (3), which is consistent with the fact that economic factors (such as business insolvencies, wage, employment, etc.) and foreign influences (the number of foreign parties in patent applications)

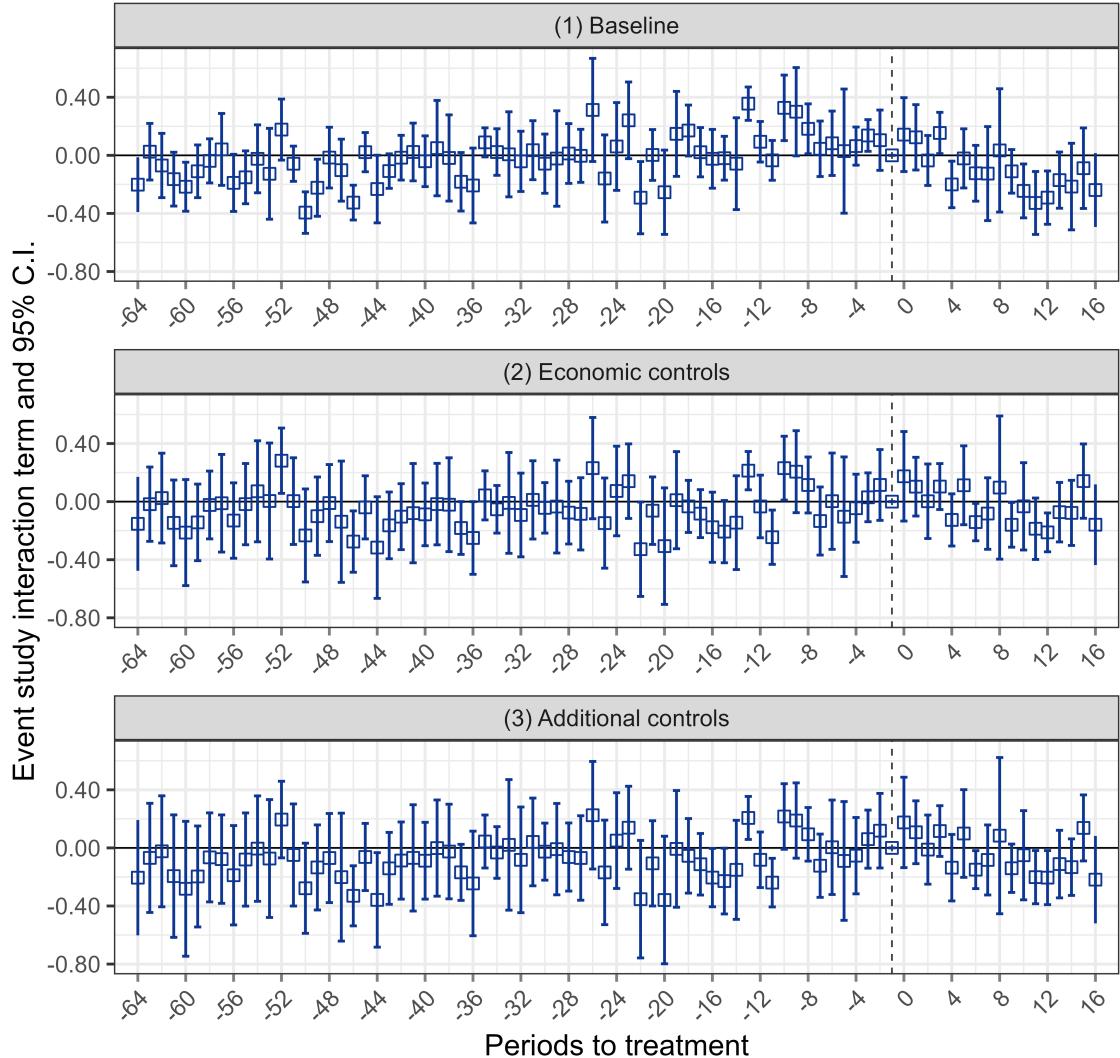
Table 3: Difference-in-differences (DD) specifications for quarterly patent applications

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

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

control for differences between treated and untreated observations.

Figure 2: Event study plots for quarterly patent applications



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

4.2 Separating by International Patent Classifications (IPC)

In Table 4, I present the results of estimating Equation 1 allowing for heterogeneity by IPC 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, D and E, corre-

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

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|-------------------|---------------------|------------------|------------------|--------------------|----------------------|------------------|-------------------|------------------|
| Treated | 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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

sponding to human necessities, textile/paper and fixed construction inventions. The effect on section A and D inventions is positive while on section E it is negative.

Approximately, it would appear that the positive effect on human necessity and textile applications is larger than the negative effect on fixed construction applications. However, given that there is a smaller number of patents per IPC section for all provinces in every period, I am underpowered to detect small effects on other sections, which could also be negative, thus explaining the null effect on total patents. The event study regressions in Figure 3 provide additional insight into the intervention's effect on patent applications by IPC section. The figure displays the same coefficients and confidence intervals as those in Figure 2, now separating by IPC section and restricting to the specification with additional controls.

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

The offsetting negative effect on fixed construction (E) inventions is difficult to interpret

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

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

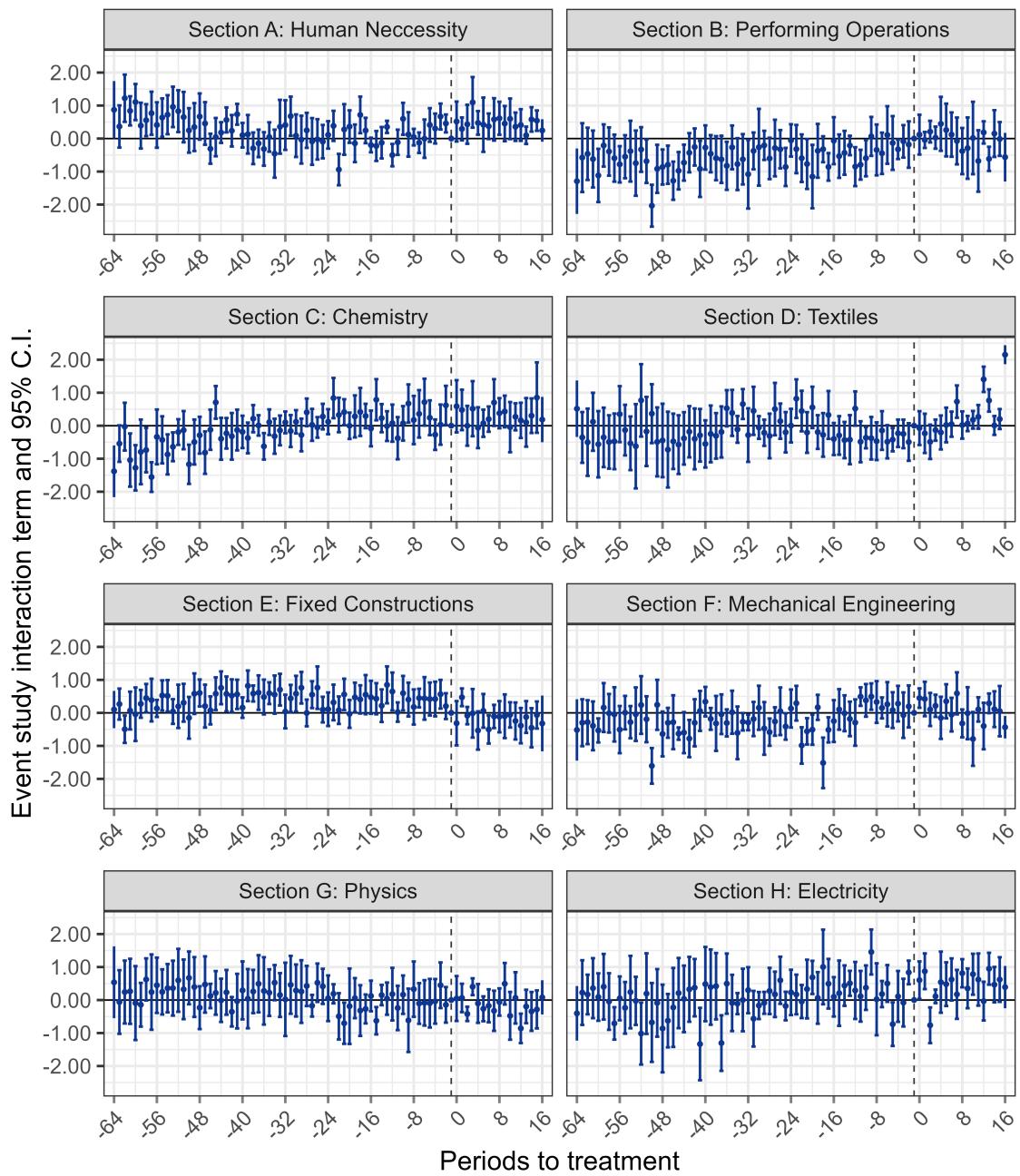
4.3 Robustness checks

Appendix B presents the results of the DD specifications and event studies for number of parties in patent applications as explained variables. All models use the controls in Specification (3) of Table 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 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 show less consistency between treatment and control groups 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 similar results in terms of statistical significance compared to results in Table 3. This means that the additional precision does not

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



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

change the existence of a null result. Regarding the event study plot, the pre-intervention months are much less stable than in the quarterly case. There are statistically significant differences in many periods before January 2017, which present themselves in an almost seasonal nature: differences start being relatively large, but as months pass they become smaller until being null. This explains why the quarterly aggregation does not show an unstable pre-intervention trend. I discuss the implications of this issue in the conclusion. In the post-intervention periods, there were months in which Alberta had fewer patent applications than the control provinces, but in the last period, these differences were not significant. Overall, post-intervention periods do not show a significant deviation from the quarterly results.

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

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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 NL, PE, YT, and NU.

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 |
| | Ln +1 Section H applications | 1.032 | 0.898 |
| | Ln +1 Multiple section applications | 3.013 | 3.007 |

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

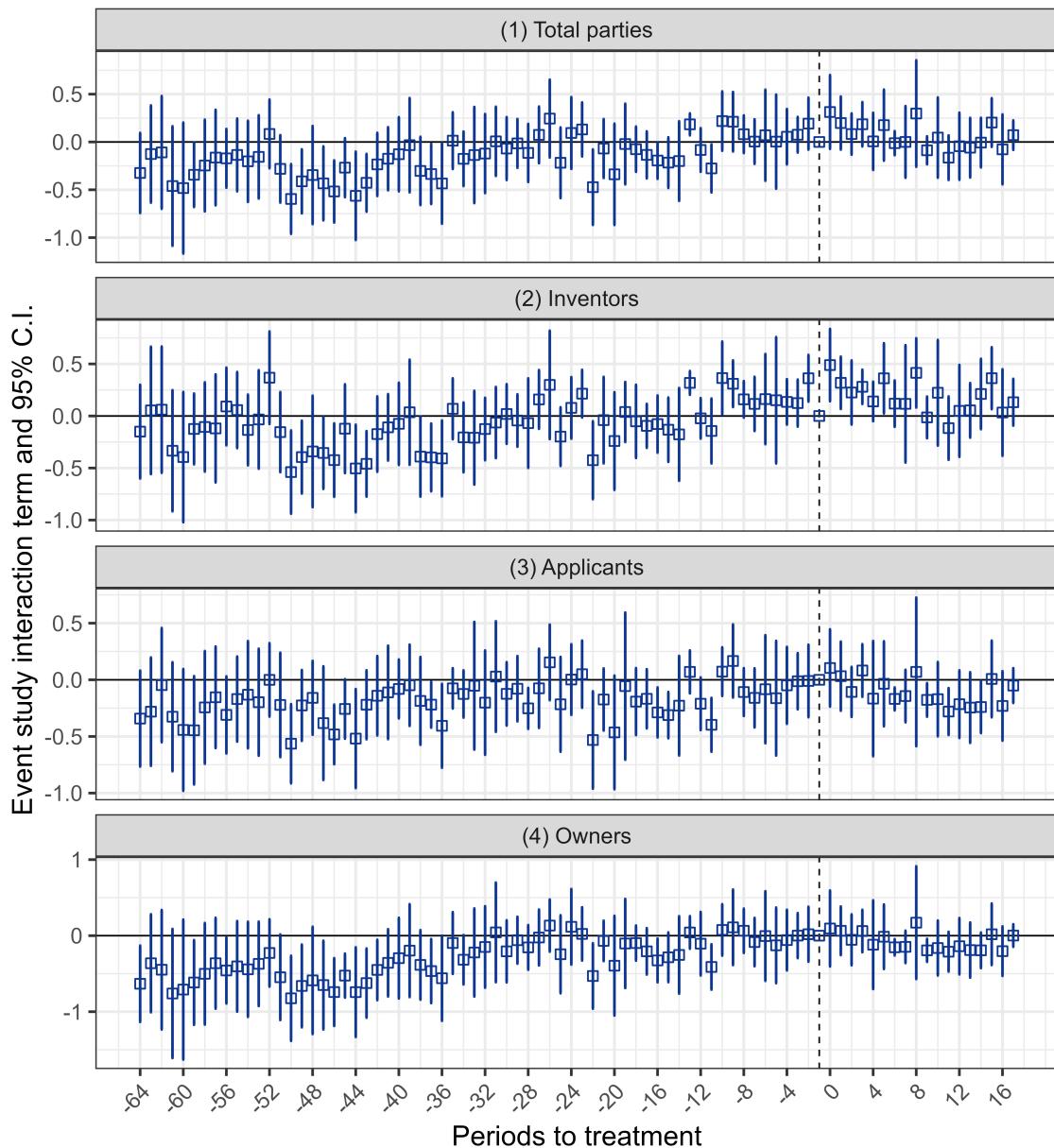
B Appendix: Patent parties models

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

| | (1) | (2) | (3) | (4) |
|-------------------|------------------|------------------|------------------|------------------|
| Treated | 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 in 2017Q1, with the reference level being the quarter before the intervention. Baseline, economic, and additional controls specifications include the controls seen in specifications (1) through (3) in Table 3.

C Appendix: Province-month panel results

Table C.8: DD specifications for monthly patent applications

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

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

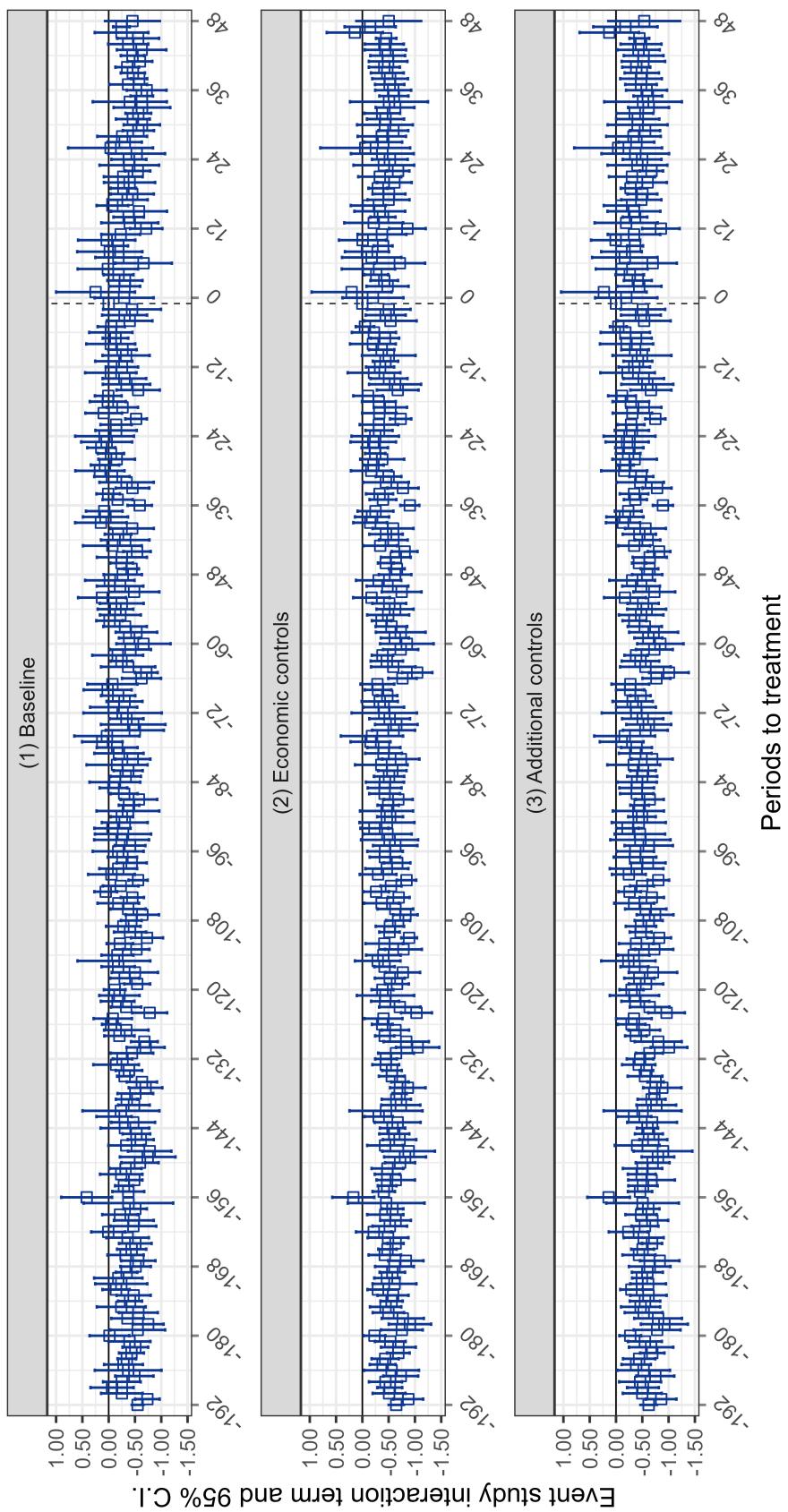
Table C.9: Difference-in-differences results for monthly patent applications by IPC section

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|-------------------|---------------------|--------------------|-------------------|--------------------|----------------------|--------------------|-------------------|-------------------|
| Treated | 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 are shown in parentheses.

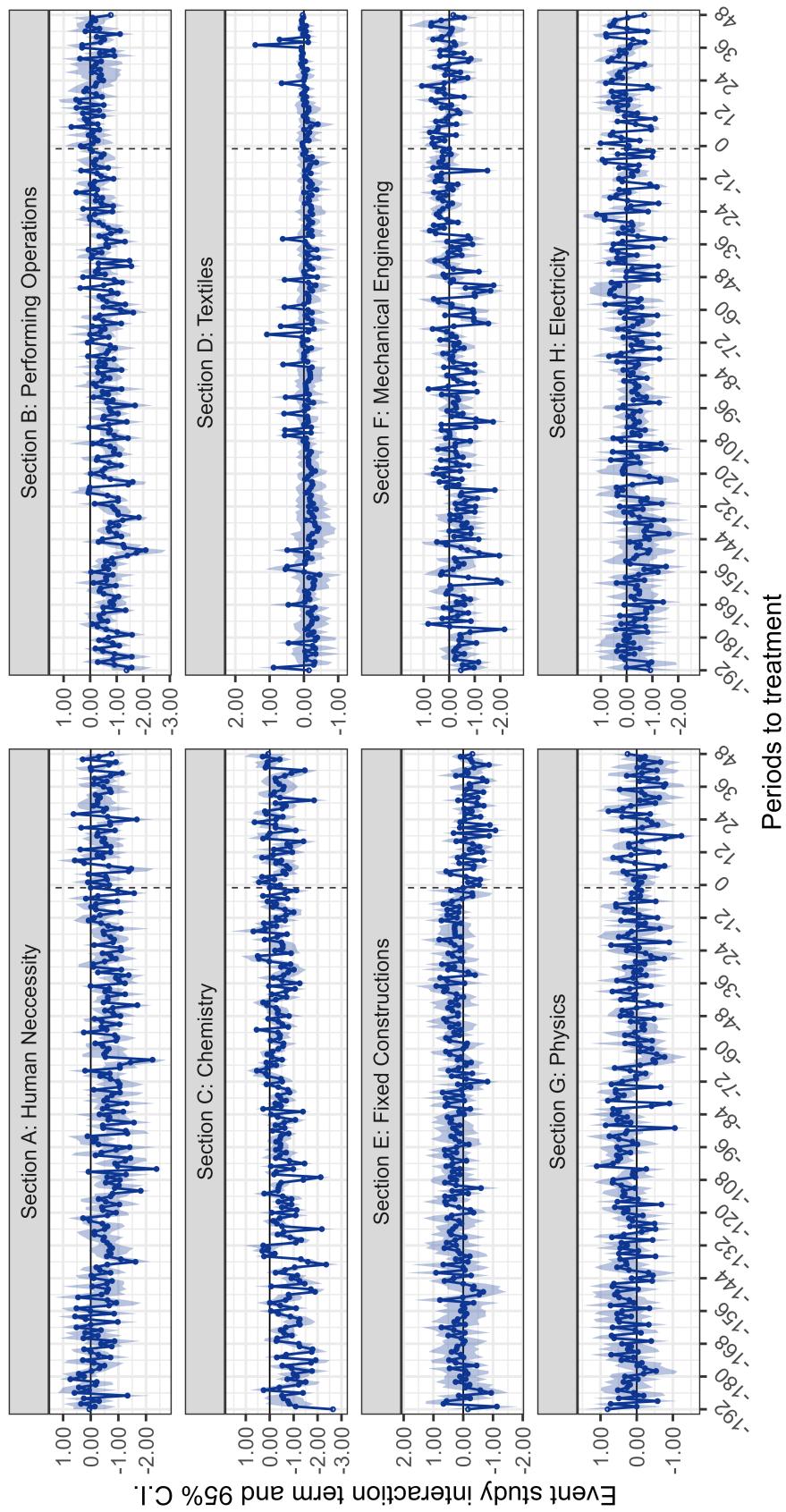
Sections of the IPC are A: Human Necessities, B: Performing Operations; Transporting, C: Chemistry; Metallurgy, D: Textiles; Paper, E: Fixed Constructions, F: Mechanical Engineering; G: Physics, H: Electricity. Patents with multiple sections are not included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure 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, separated by IPC section. The lines represent point estimates, while the shaded areas represent the 95% confidence cluster-robust intervals. The vertical line represents the start of the AITC intervention in January 2017, with the reference level being the quarter before the intervention. Controls are the same as those in Specification (3) in Table 3.