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Unboxing the Dutch Patent Box: Innovation or Profits?

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Abstract

The Netherlands was one of the first countries that implemented a patent box in 2007, reducing its corporate tax rate for royalty income. Although the initial goal is to increase R&D, patent boxes open up an extra channel for profit shifting as well. Since there is no general consent on the size of these effects, this master thesis tries to measure these effects for the Netherlands. First, this thesis offers a theoretical framework using two countries and two multinational cooperations with affiliates in both countries. From this model follows that a patent box has a positive effect on innovation and profit shifting. These predictions are consequently tested empirically via a differences-in-differences estimation method using Austria as main control group. Using data on patent applications from the OECD REGPAT database, negative results are found on the level of innovation and profit shifting. These negative findings are found as well with a fixed effects estimation. In the end, this master thesis calls the functioning of the patent box into question, such that the desirability of the tax rule is at stake.

Keywords: patent box, tax policy, innovation, profit shifting

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Contents

1 Introduction

Over the last two decades many European countries have implemented a patent box in their tax code, thereby differentiating between regular income and income derived from intellectual property.[1] The patent box intents to create more research & development (R&D)[2], by lowering the tax rate on royalty income far below the corporate tax rate, thereby increasing the competitiveness of an economy.

Although this is not detrimental in itself, the introduction of these patent boxes has created another loophole in the tax code of European countries. Multinational corporations (MNCs) can make use of the difference in the tax treatment of intellectual property income to lower their effective tax burden. By relocating the R&D units to patent box countries, another channel of profit shifting opens up by mispricing royalty payments between the MNCs' affiliates and the headquarter/R&D unit. The OECD (2015a) has made clear in its report on Base Erosion and Profit Shifting (BEPS) that stimulating innovation is an important factor of economic growth, but purely relocating the R&D to a place where it is subjected to a lower tax rate might be harmful.

In the light of the increased awareness on profit shifting done by MNCs globally, patent boxes can be considered as an important chain in the various options to shift profits. It is estimated by Tørsløv et al. (2020) that about 40% of MNCs' profits are shifted to tax havens globally, which eventually leads to a global tax revenue loss of 10%[3], thereby indicating the impact of profit shifting. Recently, the Netherlands has been put under increased international pressure due to its attractive tax climate for MNCs.[4] This has led to debates in parliament on the role of the Netherlands in the worldwide system of tax evasion.[5]

This master thesis attempts to add to this debate by having another critical look at the implementation and functioning of the patent box within the Dutch tax system. The Dutch patent box is chosen since it was the first real patent box that got implemented.[6] Since then it has been an essential instrument for governments to attract foreign direct investment (FDI).

[1] The list of countries contains Ireland, France, Hungary, Belgium, the Netherlands, Luxembourg, Spain, Cyprus, United Kingdom, Portugal, Italy, Lithuania, Slovakia, Malta, Poland, and Switzerland (by order of implementation). See Tax Foundation Report: Patent Box Regimes in Europe (2019).

[2] The terms R&D and innovation are both used frequently in this study and have the same meaning.

[3] As a percentage of total collected corporate tax revenues.

[4] The Netherlands is famous for its role as conduit country due to the "Double Irish Dutch sandwich", see Lejour et al. (2019) for more information. Although the Netherlands has not been present on many lists of tax havens, Tørsløv et al. (2020) labeled the Netherlands officialy as tax haven because of its important role in global financial flows and because of its position in the network of tax evasion.

[5] See for example Snel (2018) on international tax policy feeded by the report of Hers et al. (2018).

[6] Altough France and Ireland had preferential tax treatments on intellectual property before the Netherlands, the Dutch patent box was the first out there and has created awareness among multinationals as a means of profit shifting (Evers, 2015). After the Netherlands, many countries followed by implementing a patent box as well.

Therefore, the main research question is as follows: *"To what extent did the introduction of the patent box create more R&D in the Netherlands?"* Thereby the following questions should help estimating the effects of the patent box:

- Does the newly created R&D mostly contain domestic R&D or foreign (shifted) R&D?
- Did the implementation of the patent box create differences between the different sectors of technology?
- How did the level of R&D respond to the changes to the patent box in 2010?

If these questions are properly answered, one should have a clear view of the effects of the patent box in the Netherlands. Given the results of similar papers and the results of the theoretical framework, the hypothesis is as follows: *"The implementation of the patent box has led to more R&D in the Netherlands, both domestically and from abroad. Hence, it is expected to see more real innovation and increased profit shifting."* Unfortunately, due to data limitations it is impossible to observe R&D expenditures directly, therefore the domestic contributions to patent applications in the Netherlands are used as proxy for the level of R&D. Moreover, it is impossible to directly observe profit shifting, thus foreign contributions to patent applications in the Netherlands serve as a proxy for profit shifting.

The research question will be tested empirically via a differences-in-differences estimation method using Austria as main control group, which has not been used yet, to test the functioning of a patent box in this set-up to my knowledge. A lot is written on the functioning of the patent box in the Netherlands (mainly legal research), but empirical analysis is scarce, particularly on the first phase of the patent box.[7] This master thesis will attempt to fill this gap by doing additional research, focussing on the distinction between domestic and foreign innovation, as to include the profit shifting element as well.

In the theoretical framework, the effects of implementing a patent box are derived based on an environment with two countries and two MNCs, with each two production affiliates. The outcomes of this model illustrate that a patent box should trigger the level of domestic R&D positively and create additional incentives for profit shifting as well. Since the marginal product of technological quality is taxed at a lower rate than the corporate tax, the firm increases the amount of R&D, since the marginal benefits of technology are higher compared to a situation without a patent box. At the same time, due to the tax rate on royalty income a tax differential is created with the corporate tax rate. This increases the marginal benefits of profit shifting and therefore profit shifting should also increase.

[7] To my knowledge, the only empirical analysis on the functioning of the patent box in the Netherlands specific is den Hartog et al. (2015).

Based on the results, the empirical analysis illustrates that the implementation of the patent box has caused annually, on average, around 6.2 patent applications less per region within each sector of technology than before the implementation of the patent box. This indicates that the patent box has not caused any extra R&D in the Netherlands. To make a distinction between domestic and foreign innovation, it is found that of these 6.2 fewer patent applications, 3.6 is caused by changes in domestic innovation and 2.6 is due to changes in foreign innovation. These numbers indicate that both elements are triggered by the patent box and no difference is found in the effects of domestic innovation and foreign innovation (both parts are triggered negatively). Between sectors, no remarkable differences are found in the magnitude of the functioning of the patent box on levels of innovation. This makes clear that the patent box comprises all types of innovations, making no distinction between certain sectors.

Because of the large amendments made to the patent box in 2010, another differences-in-differences estimation is done for this period, where again negative results are found. Estimating the results within a larger time frame, a statistically insignificant coefficient of 1.4 is found assuming lagged effects. Within this 1.4 patent applications, 2.1 is caused by the change is domestic innovation, while -0.7 is caused by foreign innovation. Again, both coefficients appear to be insignificant, such that no real conclusions can be drawn from this second phase. When an estimation is done for the full sample period via fixed effects, including the tax rate on royalty income, the findings of the earlier differences-in-differences estimations are confirmed by similarities in respective coefficients. Nevertheless, the magnitude of these coefficients is larger.

1.1 Literature review

To my knowledge, this study is the first to analyse the effects of a patent box from a regional and sectoral perspective while applying a differences-in-differences estimation method. The literature on taxation of intellectual property is growing and Evers et al. (2015) have provided an overview of the characteristics of the European patent boxes. They show that boxes stimulating intellectual property lead to a reduction in effective corporate tax rates. Findings by Köthenbürger et al. (2018), as these estimate the difference in profitability between MNCs with and without intellectual property are in line with the findings of Evers et al. (2015). Compared to MNCs who did not possess intellectual property under a patent box regime, MNCs with intellectual property report on average 8.5% higher profits in their affiliates. Here the characteristics of the patent box appear to be of key importance. The specific design of patent boxes takes centre stage in the research of Gaessler et al. (2018), who report that higher requirements on patents to fall under the scope of the patent box lead to less transfers between countries.

Several papers look into the effect tax rates have on the location of intellectual property. Dischinger & Riedel (2011) show that intellectual property holdings respond negatively to tax rates within MNCs. These effects are confirmed for patent applications as well by Karkinsky & Riedel (2012) and Griffith et al. (2014), whereas each paper uses different estimation methods.[8] Alstadsæter et al. (2018) also test the relation between patent boxes and the location of patents and local R&D with a larger dataset for a period with more active patent boxes. Using an approach based on the one by Griffith et al. (2014), Alstadsæter et al. (2018) found strong effects of patent boxes on the location of patents. The literature on the topic is extended as Baumann et al. (2020) also includes the effects of patent quality as well.[9] Their results imply that the higher the quality of the patent, the more important the location of the patent, thus qualitatively better patents are relocated. These studies indicate that patent boxes have a substantial distortive effect on the location of the patent.

As other studies focus mainly on the patent applications filed at the EPO, Bradley et al. (2015) broaden the scope by including patent applications at national patent offices as well, stating the results in terms of the intended goals of the patent box. They find that the quantity of patent applications has increased due to patent boxes, but the quality of patents has fallen. The effect of corporate taxes on the quality of R&D is further investigated in the study of Ernst et al. (2014), which has found a negative relationship between corporate tax rates and the quality of patents. This conclusion contradicts the study of Bradley et al. (2015).

The rest of the paper is structured as follows: Section 2 gives a brief introduction on the implementation and functioning of the patent box and all the changes that have been made after implementation. Section 3 lays out the theoretical framework on which the empirical research rests. Section 4 describes the data, after which section 5 will consequently explain the empirical strategy. The results of the estimations can be found in section 6, and robustness analyses are done in section 7. Section 8 discusses the results and section 9 concludes.

2 The implementation of the Dutch patent box

During the Lisbon Summit on the 23rd & 24th of March 2000, the Member States of the European Union came together to set several strategic (economic) targets for the coming decade (European Council, 2000). One of the strategic goals set was that the EU should be the most dynamic and competitive economy of the world by 2010. Further agreements were made on improvements

[8] Karkinsky & Riedel (2012) use a mixed logit model while Griffith et al. (2014) use fixed effects, random effects and fixed effects negative binomial model estimations. Both papers make use of EPO data.

[9] The quality indicators included are the number of forward citations, family size and the number of technological classes. With these three indicators the authors construct a composite index for each patent.

in sustainable growth, where innovation plays a vital role. The member states consented on a minimum of 3 percent of GDP that needs to be spent on innovation and R&D. From this 3 percent, the private sector is entitled to finance two-thirds while EU governments should account for the remaining one-third (Quijada, 2016).

2.1 Octrooibox

The agreements made in Lisbon eventually led to the implementation of the patent box. On the 6th of February 2007 the rule on the patent box got included in the law on corporate income taxation (Wet op de Vennootschapsbelasting 1969), such that the patent box got implemented retroactively per 1st of January 2007. The goal of the tax rule is twofold: increasing innovation within the economy, and making the tax environment more attractive for firms such that they choose to locate their R&D in the Netherlands which results in more innovation (Zalm, 2006). The specific details of the octrooibox are listed below:

- The statutory tax rate on royalty income is 10%, while regular income is taxed at 25%[10];
- The type of intangible assets is limited to granted patents after 2007. Logo's, brands or anything similar do not fall within the scope of the octrooibox;
- The amount of income taxable at the royalty tax rate is limited to four times the development costs of the corresponding patent;
- The income must be traceable back to the R&D costs of the patent[11];
- The patent must be self-developed;
- Although externally acquired patents do not fall within the scope, the R&D may have been done abroad (Cornelisse, 2006).

Already before its implementation, the members of the parliament were aware that such a tax rule leaves room for arbitrage for firms on which profits to report. During a debate in August 2006, several politicians inquired the government why patents had been chosen as criteria for stimulating the production of intellectual property. The Minister of Finance, Gerrit Zalm, answered these questions by saying that patents give less room for arbitrage in comparison to other forms of intellectual property, such as brands and logo's (Zalm, 2006). This was prior

[10] There is made a distinction between income below and above EUR 200,000. The first EUR 200,000 income is taxed at 20%, everything above EUR 200,000 is taxed at 25%.

[11] In an explanatory session the Secretary of State already confessed that this requirement is difficult to verify and hence additional guidelines and restrictions are needed. From this one can conclude that there is lots of room for arbitrage.

to the publication of the OECD report on Base Erosing and Profit Shifting (BEPS), such that there was less awareness on the scale on which profit shifting can take place. Several other members of parliament also inquired why the government had chosen to stimulate R&D via the income side, and not via the cost side (e.g. subsidies). No clear answer was given at the time. Looking at these findings, it may be obvious that there was enough support to stimulate R&D, but there seemed little concensus as to whether a patent box would be the right way to do so.

2.2 Innovatiebox

In 2009, Jan Kees de Jager - the Secretary of State - concluded that the patent box in its current form was not functioning as intended. The government received many criticisms about the complexity of the tax rule, which seemed to limit firms from applying it to their business due to potentially high administration costs.[12] Another barrier seemed to be that the rule can only be applied to granted patents, while many firms are in doubt to patent their product at all.[13] If they consider the innovative value of the product to be small, many firms will not apply for a patent, since all the benefits are not taken into account.[14] Thereby, deductibility of losses was a substantial drawback for firms that applied the tax rule to their business. Losses on R&D activities were only deductible at 10% if the patent box was applied, while firms without the patent box could deduct those losses at 25%. In essence, even if firms already had overcome the complexity of the rule, they could get punished by applying the rule in the absence of profits (which was a considerable threat in 2009)[15].

On Little Prince Day 2009, the changes to the patent box were introduced so that the tax rule would become more attractive and better accessible to small and medium sized firms. The central idea of the amendment was to widen the scope of the patent box to all innovation, whereas the previous structure focussed mainly on patents. Other changes included: lowering the patent box tax rate from 10% to 5% (while the corporate tax rate remained 25%, see footnote 10), removing the maximum on entitled income regarding the patent box[16], removing the maximum of EUR 400,000 for other forms of R&D (as mentoned in footnote 16), and the obligation to report losses under the patent box (making losses tax-deductible at the regular corporate tax rate) (de Jager & Bos, 2009). Nevertheless, the patent box remained controversial because of efficiency reasons. For example, only corporations can make a claim on the patent

[12] van Kalles, B. (2009, August 20). Staatssecretaris De Jager verruimt octrooibox. *Het Financieele Dagblad*, p. 3.

[13] This already got amended in 2008 by approving R&D that had received a specific declaration for another tax rule favouring R&D (WBSO) in Kortenhorst & Tang (2007). In short, firms could receive a subsidy based on a given percentage of the salaries of employees that worked on R&D.

[14] Groot Koerkamp, J. and Jansen, B. (2009, October 10) Octrooibox. *Het Financieele Dagblad*, p. 9.

[15] For example, industrial economic value added decreased with 8.8% for the Netherlands in 2009 (CBS, 2010).

[16] Before the 2010 amendment, this maximum used to be four times the costs of the respective R&D.

box since the tax rule falls under the scope of the corporate tax. Sole proprietorships and partnerships fall under the personal income tax and cannot make use of the patent box. This is a shortcoming since a lot of startups are commonly no corporations yet.[17] Consequently, realising that the expenses of the patent box are about EUR 600 million and rising[18], it seems to be an ineffective tax rule that favours the profit maximisation of large firms.

2.3 Later amendments

Forthcoming from the presentation of the OECD action plan on Base Erosion and Profit Shifting the discussion on the patent box got fueled, both internationally and domestically. Action point number 5 describes key points on how harmful tax rules could be countered. For example through the requirement of substantial activity, which implies an improved nexus approach such that the ones benefetting from the rule should also be the ones that conducted the activities (OECD, 2015b). Secretary of State Eric Wiebes therefore announced several amendments to the patent box per 1st of January 2017 such that regulations are more strict and a distinction is being made between R&D that has been done by the firm itself, or by external parties (the nexus approach).[19] Another distinction that is being made is one between small and large tax payers, as the Dutch tax authority has named it, based on the gross benefits of intangible assets falling under the patent box (Belastingdienst, 2020). If these benefits reach a certain treshold, additional requirements need to be met by 'large taxpayers'.[20] This distinction appeared to be needed as mainly large firms took advantage of the patent box.[21] Following a decrease in the corporate tax rate from 25% to 21.7%[22] up to 2021, the government decided to increase the tax rate on royalty income to 7% in 2018, eventually reaching 9% in 2021.[23]

3 Theoretical framework

To understand through which channels a patent box affects R&D expenditures and profit shifting, a simple but useful model is developed in this study. In this model the initial goal of patent

[17] Overduin, C. (2010, January 7). Elk bedrijf heeft recht op de innovatiebox. *Het Financieele Dagblad*, p. 6.

[18] van Kalles, B. and Mulder, T. (2009, September 17). Kabinet steunt innovatie via fiscus. *Het Financieel Dagblad*, p. 4.

[19] (2015, October 12). Belastingontwijking ligt op de loer bij de innovatiebox. *Het Financieele Dagblad*, p. 2.

[20] As the standard requirement is having a "S&O declaration" (as is needed for the WBSO tax rule), large taxpayers need to have additional requirements, such as having a patent or plant breeders' right for intellectual property. See Belastingdienst (2020) for further details.

[21] Berentsen, L. (2015, January 14). Vooral grote bedrijven profiteren van innovatiebox. *Het Financieele Dagblad*, p. 8.

[22] From 20% to 15% for profits below EUR 200,000, see footnote 10. The rates metioned in the main text are for profits above EUR 200,000.

[23] Stevens, L. (2019, October 8.) Fiscaal gehussel met tarieven kan het evenwicht aantasten en ongewenste scheefgroei veroorzaken. *Het Financieele Dagblad*, p. 25.

boxes forms the basis; namely, increased research and development. The theoretical framework is based on several relevant studies, such as Köthenbürger et al. (2018) and Haufler & Schindler (2020), which develop models on the topic of R&D and profit shifting. The model developed in Köthenbürger et al. (2018) has some interesting properties, but patent boxes are not included and consequently oversimplifies. To make their model suitable for this study, multiple elements from Haufler & Schindler (2020) are included, such that the theoretical framework becomes more consistent and sophisticated. In the end it is found that a patent box increases both R&D output and profit shifting, where the magnitudes are determined by the slopes of the production and cost function and the height of tax rates.[24]

3.1 Set-up

Suppose an environment with two symmetric countries, A and B. In each country resides a MNC with one production affiliate in each country, $i = A, B$ and a R&D unit in the country of the headquarter. Hence, in total two MNCs. The R&D unit located in country j produces a production technology for the production affiliates. The quality q^j of this technology depends on the effort put into R&D e^j and is generated using a concave R&D production function

$$q^j = q(e^j), \text{ where } j = A, B \text{ with } q_e^j > 0, q_{ee}^j < 0.^{25} \tag{3.1}$$

The related costs of innovation are given by the convex cost function

$$c(e^j), \text{ where } c(0) = 0,\ c_e(e^j) > 0,\ c_{ee}(e^j) > 0. \tag{3.2}$$

These costs are not tax-deductible, which is a viable assumption. If, for example, the inputs are financed by equity, it could easily be the case that these costs are not tax-deductible.

Production affiliate i uses the MNC-specific technology q^j and capital k_i^j as inputs to produce a homogeneous output good y that is sold at the world-market price, equal to unity. The production function of each affiliate is given by

$$y_i^j = f(q^j, k_i^j), \text{ with } f_q > 0,\ f_{qq} < 0,\ f_k > 0,\ f_{kk} < 0, f_{kq} > 0. \tag{3.3}$$

This implies that both technological quality and capital have positive marginal productivities,

[24] This mainly depends on how the functions respond on one unit of input more or less; e.g. whether one unit output produced more increase total costs slightly or heavily.

[25] There are multiple types of subscripts in the model. The subscripts i and j relate to the MNC and country respectively. Any other subscript implies the function is a partial derivative of the relevant subscript. For example, q_e^j is the first partial derivative for e of the function $q^j(e^j)$ for country j.

but marginal productivities are decreasing with the amounts of inputs used in the production process. As can be seen in the last term above, technological quality and capital are complements since the marginal productivity of capital input k_i^j depends positively on technological quality q^j.

Each affiliate pays a royalty fee to its R&D unit to remunerate the use of the technological input in the production process. The royalty payment is given by $p_i^j = \gamma_i q^j(e^j) + a_i^j$. The first part of the function is the arm's length payment where the arm's length price is determined by the marginal productivity of the technology, i.e., $\gamma_i = f_q(q^j(e^j), k_i^j)$. The tax authority can only observe the average quality of technology and the marginal product in the local market and therefore the arm's length price is determined on the average marginal product of technological quality on the market (Haufler & Schindler, 2020). This price is treated exogenous by each MNC. Moreover, the second term indicates that the MNC can misprice the royalty fee in order to shift profits. Here a_i^j represents the amount of overpricing, i.e. excessive royalties in the form of profit shifted to the R&D unit. Nevertheless, mispricing the technological quality is costly and leads to tax planning costs for hiring accountants and tax consultants.[26] These concealment costs for mispricing are given by the convex function

$$\theta = \theta(a_i^j), \text{ where } \theta(0) = 0, \ \theta_a(a_i^j) > 0, \ \theta_{aa}(a_i^j) > 0. \tag{3.4}$$

Whether costs are tax-deductible does not matter for the qualitative outcome. So, to avoid redundancy, these costs are made not tax-deductible to save notation. Moreover, it does therefore not matter whether production affiliate, R&D unit, or the parent company incurs the concealment cost.

The international capital market is perfectly integrated and both countries and MNCs are small compared to the market. All capital is equity financed, and not tax-deductible (which is in line with most tax codes of OECD countries). The cost of capital is given by r, exogenous for each MNC and invariant to changes in tax instruments.

Each country j charges a statutory corporate tax rate t_i on profits in the production affiliate and one of the countries sets a special tax rate τ_j on royalty income ('the patent box') that is booked on patents located in the country (i.e., developed in the domestic R&D unit), where $t_i > \tau_j$.

[26] See Kant (1988) and Haufler & Schjelderup (2000) on how concealment costs affect profit shifting.

3.2 Firm behaviour

The profit function of affiliate i of MNC residing in country j consists of the after-tax benefits of production minus the royalty fee, cost of capital and the concealment cost. The function is given by

$$\pi_i^j = (1 - t_i)[f(q^j(e^j), k_i^j) - p_i] - rk_i^j - \theta(a_i^j). \tag{3.5}$$

The profits of the corresponding R&D unit are made of the after-tax benefits of the royalty payments from the production affiliates minus the cost of R&D effort. The profit function is thus given by

$$\pi_{R\&D}^j = (1 - \tau_j) \sum_{i=A,B} p_i^j - c(e^j). \tag{3.6}$$

The total global after-tax profits of a MNC with headquarters and R&D unit in country j can be summarised as the profits from the production affiliates A and B. The function therefore looks as

$$\begin{aligned} \Pi_M^j &= \pi_A^j + \pi_B^j + \pi_{R\&D}^j \\ &= (1 - t_a)[f(q^j(e^j), k_A^j) - p_A] - rk_A^j - \theta(a_A^j) \\ &+ (1 - t_b)[f(q^j(e^j), k_B^j) - p_B] - rk_B^j - \theta(a_B^j) \\ &+ (1 - \tau_j) \sum_{i=A,B} p_i^j - c(e^j), \end{aligned} \tag{3.7}$$

where $p_i^j = \gamma_i q^j(e) + a_i^j$. The consolidated after-tax profits are maximised with respect to k_i^j, e^j, a_i^j and are according to the function

$$\begin{aligned} \max_{k_i^j, e^j, a_i^j} \Pi_M^j = (1 - t_A) f(q^j(e^j), k_A^j) + (1 - t_B) f(q^j(e^j), k_B^j) - r(k_A^j + k_B^j) - c(e^j) \\ + (t_A - \tau_j)[\gamma_A q^j(e) + a_A^j] - \theta(a_A^j) + (t_B - \tau_j)[\gamma_B q^j(e) + a_B^j] - \theta(a_B^j). \end{aligned} \tag{3.8}$$

Moreover, the MNC residing in country j chooses the inputs R&D effort e^j, capital k_i^j and the excessive royalty payment a_i^j such that it maximises the consolidated profit function as described in equation (3.8). This gives the first-order condition

$$\frac{\partial \Pi^j}{\partial k_i^j} = (1 - t_i) f_k(q^j(e^j), k_i^j) - r = 0, \; i = A, B. \tag{3.9}$$

Equation (3.9) tells us that in the optimum, the marginal benefits of capital k_i^j used in the production process, i.e. the marginal productivity of capital, should be equal to the marginal costs of capital, which is r. By differentiating the MNCs' profit function for the R&D effort, the next first-order condition is given by

$$\frac{\partial \Pi^j}{\partial e^j} = \sum_i (1-t_i) f_q(q^j(e^j), k_i^j) q^j(e^j) + \sum_i (t_i - \tau_j)(\gamma_i q_e^j(e^j)) - c_e(e^j). \tag{3.10}$$

Given that the marginal product of technological quantity is equal to the arm's length price $\gamma_i = f_q(q^j(e^j), k_i^j)$, the first-order condition above can be further simplified to

$$(1-\tau_j) \sum_i f_q(q^j(e^j), k_i^j) q_e^j(e^j) = c_e(e^j). \tag{3.11}$$

Equation (3.11) shows that the optimal amount of effort e^j put into R&D is determined in such a manner that in the optimum the marginal after-tax benefits of R&D effort within the production process are equal to the marginal costs of R&D effort. The last first-order condition implies that the optimal amount of shifted royalties is determined such that the tax differential between the statutory corporate income tax rate of the affiliate and the tax rate on royalty income equals the marginal costs of shifting royalties. This gives

$$\frac{\partial \Pi^j}{\partial a_i^j} = (t_i - \tau_j) - \theta_a(a_i^j) = 0, \; i = A, B \tag{3.12}$$

In this case, it implies that the marginal benefits of profit shifting, i.e. marginal tax savings, are equal to the marginal costs of shifiting, which are given by the concealment costs $\theta_a(a_i^j)$.

3.3 Comparative static responses to tax rate changes

From the derivations of the comparative statics in appendix A.2 we find

$$\frac{de^j}{dt_i} < 0. \tag{3.13}$$

An increase in the corporate tax rate t_i in production affiliate i causes the MNC to lower the input of technological quality e^j in the production process, and thus leads to lower demand for technological quality. Due to the increase in the corporate tax rate, the wedge between social and private (corporate) benefits of technoligical quality increases. As a result of this additional distortion, the after-tax return on technological quality decreases and the firm responds by lowering its input e^j in the production process.

$$\frac{de^j}{d\tau_j} < 0 \tag{3.14}$$

In term (3.14) is shown that an increase in the tax rate for royalty income affects the level of effort in technological quality negatively. This can be explained by the fact that the tax rate on royalty income widens the wedge between social and private (corporate) returns on technological quality, since the after-tax return is lowered. Given that costs are not tax-deductible either, the firm responds by lowering the input e^j.

$$\frac{dk_i^j}{dt_i} < 0 \tag{3.15}$$

In term (3.15), it is found that an increase in the corporate tax rate causes the firm to lower the amount of capital in the production function. The reasoning is the same as in the first term, the after-tax return of capital is decreased due to the higher corporate tax rate. Because of this, the firm lowers the capital inputs k_i^j in the production function.

$$\frac{dk_i^j}{d\tau_j} < 0. \tag{3.16}$$

In (3.16) it can be seen that the amount of capital is negatively triggered by a positive change in the tax rate for royalty income. Given that capital and technological quality are complements, technological quality responds negatively on a rate increase in the tax on royalty income, which makes capital less productive and capital demand falls such that capital inputs in the production function are decreased.

At last, the findings on profit shifting are discussed. In term (3.17) it is found that

$$\frac{da_i^j}{dt_i} > 0. \tag{3.17}$$

As the corporate tax rate increases, the differential with the tax rate on royalty income widens[27], such that the marginal benefit of profit shifting grows. This increases profit shifiting incentives, and hence the amounts of shifted profits is increased by the firm.

$$\frac{da_i^j}{d\tau_j} < 0 \tag{3.18}$$

The last term shows that a higher tax rate on royalty income has the opposite effect of an increase in the corporate tax rate. The differential between the corporate tax rate and the tax rate on royalty income becomes smaller, such that the marginal benefits of profit shifting decline and the amounts of profit shifted are lowered by the firm.

These findings are roughly in line with the findings of Haufler & Schindler (2020), except

[27] Here the essential condition for a patent box $t_i > \tau_j$ must hold.

that they find a positive response of technological input due to a corporate tax rate increase. In that situation, there appears to be a strong substitution effect leading to the supply of more technological input, compared to the negative supply response in this model. In their findings, the higher corporate tax rate affects cost of capital negatively, and therefore costs of technological quality decrease such that the input R&D effort increases (Haufler & Schindler, 2020).[28]

3.4 Tax revenue

Tax revenue in country A is given by taxing the production affiliates of the two the MNCs, plus the tax revenue from the patent box (the same would hold for country B if their government would implement a patent box since both countries are symmetric). Therefore, tax revenue is given by

$$\begin{aligned} T_A = & t_A[f(q^A(e^A), k_A^A) - \gamma_A q^A(e^A) - a_A^A + f(q^B(e^B), k_A^B) - \gamma_A q^B(e^B) - a_A^B] \\ & + \tau_A[\gamma_A q^A(e^A) + a_A^A + \gamma_B q^A(e^A) + a_B^A]. \end{aligned} \tag{3.19}$$

From this tax revenue function, three different effects can be seperated from a decrease in the patent box rate τ_A:

(+) Higher R&D effort leads to more technological quality, higher production and therefore more tax revenue (also to more arm's length payments from country B).

(−) More profits are shifted by the domestic MNC from the domestic production affiliate to the domestic patent box tax base. This leads to a reduction in total tax revenue.

(+) More profits are shifted by the domestic MNC from the foreign production affiliate to the domestic patent box. This increases domestic tax revenue (and steals tax base from foreign countries).

4 Data description

To test the hypothesis, information is needed on the level of research & development within countries. Since this study focusses on the implementation of a patent box, these levels of research & development need to be specified more in terms of patents. Therefore, information is used on the amount of patent applications in the Netherlands and in a few other countries,

[28] In Haufler & Schindler (2020) costs of capital are given by the world market interest rate and technological quality is given by R&D investment.

such that we can compare the developments between different areas, and differentiate on the real effect of implementing a patent box.

4.1 Sources

For this study the OECD REGPAT Database has been used. This database contains information on patents from all the OECD countries over a large time period. Unique to this database is its regional scope, denoted in NUTS levels.[29] This can supply valuable information on differences between certain areas. Although several other studies on patents (Baumann et al., 2020; Gaessler et al., 2018; Bradley et al., 2015) make use of the database of the EPO (European Patent Office), mostly in combination with the Bureau van Dijk ORBIS / AMADEUS database, this will not always lead to successful outcomes since combining patent data with firm level data can be difficult and incomplete in Orbis. Another more practical reason for using the OECD REGPAT Database in this thesis is that this source is freely available, whereas access to the EPO database needs to be purchased.

Moreover, the REGPAT Database contains patent data from three different patent organisations; the EPO, the PCT (Patent Cooperation Treaty) and the USPTO (United States Patent and Trademark Office). All these three organisations have a different scope, the EPO focusses on Europe, the PCT has a more international scope, and the USPTO has an American scope. The available information on the EPO patent applications is selected because information on these patents applications is guaranteed to be clean and complete.[30] Looking at the international character of the institution, the data is designed for analysis between countries (Maraut et al., 2008). Choosing the EPO patent applications seemed to be a sensible choice for this study given the European scope, highest quality of the data and because of compatibility with patent quality indicators.

From the available time frames in the OECD REGPAT Database, the period from 2001 to 2015 is selected. Due to technical reasons, only the patents are selected which are applied for in one single country and are invented in one single region are selected. So, a patent that is invented in the region of Amsterdam and the region of Rotterdam will not be selected, but a patent that is invented in Amsterdam and abroad and applied for in the Netherlands will be selected.[31] Fortunately, the amount of patents that consequently had to be excluded from the

[29]NUTS stands for Nomenclature of Territorials Units for Statistics and is an European Union concept with the purpose of generating useful statistics between different areas (Eurostat, 2020).

[30]Maraut et al. (2008) show that the quality of the data is highest for the EPO patents.

[31]More advanced data processing methods and software is needed to include multiple regions from the same country. There have been made multiple attempts to include this as well, but every try gave incorrect outcomes with respect to the calculated shares (see subsection 4.2 on the calculation of these shares). Therefore the decision has been made to leave these patents out of the sample. The calculations could be made without errors for patents

research was only small. In the end, 97,582 patent applications are available for the period of 2001–2015.

Within the data, two different dates can be distingiushed with regard to the origin of the patent application. The first date is the so-called priority year. This is the year in which the first filing for the patent took place, and is therefore closest to the actual date of invention. According to Maraut et al. (2008), this year should be taken into account when looking into technological achievements. However, as this research focusses only partly on technological achievements, it might also be interesting to use the application year as reference date for each patent. Although it has not been mentioned in any other relevant paper (to my knowlegde), firms could use the difference between priority date and application date in their interest for tax purposes.[32] Since it might be relevant to check what the results would be under the application year as reference date, this will be done as robustness check later on in the study. Nevertheless, the difference between the priority year and application year is only small and at most two years.

The value of innovations protected vary substantially among patents, and therefore the number of patent applications alone does provide limited information (Lanjouw et al., 1998). Further information is needed to assess the economic value of a patent. Next to the REGPAT Database, the OECD Patent Quality Database comprises detailed information on patents. Where the REGPAT Database focusses on the regional aspect of patents, the Patent Quality Database shares – as one may expect – information on the technological value of patents. This information stems ultimately from the EPO. Information on the quality of the patent may be relevant for this study to test whether there might be a relationship between the technological value of the patent and the place of invention, or whether a patent box creates qualitative better patents compared to regions without a patent box.

Within the Patent Quality Database, several variables are available which tell something about the technological value of the patent. Firstly, the patent family size is the number of patent offices to which protection has been asked for. Therefore, the higher this number, the more promising the invention might be and the higher the technological value of the patent (Squicciarini et al., 2013). Secondly, the number of claims indicates the boundaries of the exclusive rights of the patent owner. The more claims a patent has, the more rights, and the higher the expected market value (Tong & Frame, 1994). Thirdly, the number of forward citations also plays an important role as it counts the amount of citations that a patent receives

with different foreign regions, and therefore these are kept in the sample.

[32] Assume that a firm has developed some promising technology, and is willing to patent it. If the firm posseses some inside information and knows that next year a patent box will be implemented, it has incentives to postpone the official application of the patent as the firm can save on taxes on patent income.

over a certain time frame. This value represents the economic value of the invention to a certain extend (Trajtenberg, 1990). These three different variables should give an extra dimension to the changes in the amounts of patents applied.

With regards to the remaining control variables the study also relies on data made available by the OECD. Given that the data on patents is available per NUTS 3 region, it would be optimal to have this information for the control variables as well. The OECD Regional Database provides this information for the time frame of this study on GDP size and population size. By dividing these values by the national amounts, one can find the shares that each has in the national total, and therefore control for region size. The control variables are complemented with the statutory corporate income tax rate, which are retrieved from the national tax authorities and the Worldwide Corporate Tax Guide from Ernst & Young.

4.2 Matching applicants with inventors

To make the OECD REGPAT Database suitable for this study, several steps had to be taken. Firstly, the patent applications file was filtered for only relevant patent applications.[33] Thereby, applications within only one single domestic region were kept in the sample, as decribed in the previous subsection (see footnote 31). Secondly, the patent applications were matched with the inventions based on the universal EPO application number. This created a list of more than 214,795 inventors matched with the corresponding applications.[34] The total list of applications was copied and checked for duplicates, which led to an amount of 97,582 patent applications for the period of 2001 to 2015. Thirdly, a variable named *domestic invention share* is constructed by calculating the domestic part of each invention via

$$y = \sum(\psi \times \mu). \tag{4.1}$$

In eqution (5.1), y represents the variable *domestic invention share*, ψ are the domestic inventors and μ is the share of each inventor in the respective invention.[35] This variable is expected to provide the study with essential information and is thus carefully checked for errors. By calculating the variable *domestic invention share*, the variable *foreign invention share* is calculated as well. For each patent, the share of domestic and foreign inventors must sum up

[33]In this case, relevance implies the countries and time frame of interest as denoted in the next subsection.

[34]The total amount of inventors is far larger than the amount of applications since an invention has multiple inventors often.

[35]For example, assume that some intellectual property in the form of an invention is created by three researchers. Two of them reside in the Netherlands and the third one resides in Germany. The variable *domestic invention share* would be equal to 0.67 for this patent application. The variable *foreign invention share* is by definition equal to 0.33 in this case.

to 1 by definition. By subtracting the domesic invention share from 1, the foreign share of each application is calculated. Fourthly, these individual shares are summed up by region and sector of technology, such that the variables *domestic invention contribution* and *foreign invention contribution* are calculated.[36] Fifthly, due to the regional aspect of the database, location information is available for all patents and a panel dataset is constructed based on NUTS 3 regions and sectors in which the patents got applied for. Lastly, patent quality indicators and additional control variables were added to complement the dataset.

Table 1: Average regional and sectoral characteristics by country (2001-2015)

	Austria			The Netherlands			Norway	
	Mean	SD	Difference	Mean	SD	Difference	Mean	SD
Patent applications	7.842	15.824	11.629***	19.471	87.55	15.111***	4.36	7.461
Domestic invention contribution	6.718	12.554	7.222***	13.94	62.364	10.273***	3.667	6.085
Foreign invention contribution	1.123	3.998	4.407***	5.53	28.913	4.837***	0.693	2.113
Corporate tax rate (%)	27.4	4	1***	28.4	4.1	0.5***	27.9	0.3
GDP per capita (USD)	42200	11080	734**	42934	11026	1563***	41371	10192
GDP size (m USD)	11400	17500	8400***	19800	21100	7400***	12400	10000
Population size (tsd)	237	269	175***	412	311	139***	273	146
Family size	3.18	2.682	0.804***	3.984	3.043	0.141	3.843	3.679
Claims	8.74	6.572	1.847***	10.587	6.411	2.998***	7.589	7.492
Forward citations	0.442	0.711	0.119***	0.561	0.903	0.248***	0.313	0.611
Observations	2625			3000			1425	

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels using a t-test of differences assuming unequal variances between groups. The differences are in comparison to the Netherlands. The average amount of patent applications is given within region, per sector. The corporate tax rate is the same for all regions within a country. GDP per capita, GDP size and population size are given as averages for each region. The family size, claims and forward citations are given per sector, within each region.

Table 1 gives the average characteristics per sector within each region for each of the variables by country over the sample period 2001 to 2015. The differences between countries are evaluated using a two-sided t-test assuming unequal variances. It appears that the Netherlands differs signficantly on many variables compared to Austria and Norway. The only similarities between the Netherlands and control groups is on the family size of the patent, compared to Norway. Although significant differences between treatment and control group are generally not optimal, they are of little importance as long as the assumption of the common trend holds.[37]

[36] This is done such that the variables of interest provide information on absolute levels of innovation and profit shifting, while the domestic and foreign invention shares only provide information on relative levels of innovation and profit shifting.

[37] See the next section on the empirical strategy for more information on the role of the common trend in the empirics, and the results section where the common trend assumption is tested (in)formally.

5 Empirical strategy

The empirical analysis focusses on the time frame around the implementation of the patent box in the Netherlands, including a rate decrease on royalty income three years after implementation. The period of interest therefore spans from several years prior to implementation to several years after the rate decrease. This is important as R&D is time-consuming and firms are assumed not to be able to develop inventions within a small period of time (Köthenbürger et al., 2018). Therefore, one should use a time frame large enough to identify the effects of R&D-relevant policies over several years.

In the ideal situation, R&D spending and profit shifting would be directly observable. Unfortunately, these variables are not directly available and observable such that proxies are needed to have a measure of it. The proxy for R&D spending stands for the level of domestic contributions to patent applications made in a region on a yearly basis. The proxy for profit shifting is the level of foreign contributions to patent applications made in a region annualy.[38] This suits this study particularly well as the patent box lies at the heart of this analysis and patent-relevant variables would therefore make a good measure. Given the findings of the theoretical model, the hypothesis is as follows; namely that the implementation of the patent box has both led to higher domestic and foreign contributions to patent applications. This implies that a patent box leads to more real innovation and more profit shifting.

5.1 Differences-in-differences estimation

To test whether the implementation of the patent box has led to more innovation, this study needs to rely on estimation methods which are suitable for testing a policy implementation. Given the scope, as we look at a policy implementation nation-wide, a *differences-in-differences* method first comes to mind to test the hypothesis empirically. Originally, the differences-in-differences method is a simple and clear way of investigating whether a policy has had impact on the variable of interest for the treatment group, while there has been no policy implementation in the control group. Thus, treatment induces a deviation from the common trend. The identifying assumption therefore is that both treatment and control group follow the same trend in the absence of treatment. The differences-in-differences method is a famous way to analyse policies implemented for large regions since treatment and control group may differ from each other in background characteristics as the region fixed effect captures these differences (Angrist & Pischke, 2008).

The method becomes clear when shown in its simplest form. In this case, the differences-

[38]For more information on these variables, see section 4.2.

in-differences estimator is given by

$$[E(y_{rt}|r=1,t=1)-E(y_{rt}|r=1,t=0)]-[E(y_{rt}|r=0,t=1)-E(y_{rt}|r=0,t=0)]. \quad (5.1)$$

In equation (5.1), y is the variable of interest, r denotes whether it concerns the treatment region and t gives the time period. By differentiating both on treatment and time, differences in background are canceled out, and one finds the causal effect of treatment (given that the common trend assumption holds). Since the data contains more than two time periods, it allows to conduct the analyis in regression format, which will be explained further on.

Within the estimation technique, multiple variables need to be tested. Firstly, we would like to know whether the implemenation has triggered more patent applications since its implementation in 2007. To test this, we have the variable *applications* on which a differences-in-differences will be run. Secondly, within the possible change in patent applications, it is vital to know whether this contained newly created R&D, or foreign imported (shifted) R&D. To differentiate between newly created R&D and shifted R&D, the variables *domestic invention contribution* and *foreign invention contribution* are created.[39]

$$Z_{rst} = Y_{rst} + X_{rst}$$

The total amount of patent applications Z in a region are composed of domestic inventions Y and foreign inventions X. These three variables are the variables of interest within this study. Therefore, the baseline equation for the differences-in-differences estimation is given by

$$\Omega = \beta_0 + \beta_1 PB_{jt} + \beta_2 D_{jt} + \beta_3 T_{jt} + \eta_{rt} + \lambda_{rst} + \gamma_t + \epsilon_{rst} \quad (5.2)$$

Here Ω represents the three variables of interest on which the estimations will be done, as shown below.

$$\Omega = (Z_{rst}, Y_{rst}, X_{rst})$$

Hence, Z_{rst} is the number of applications done in region r, in sector s, for the year t. The same holds for the amounts of domestic and foreign invention contributions, Y_{rst} and X_{rst}. The variable PB_{jt} indicates whether it concerns a patent box regime, hence a group-specific dummy for the Netherlands. The variable of interest is constructed by interacting the time period that the patent box has been active with the patent box regime dummy PB_{jt}. This yields the coefficient of interest β_2 and should give the effect of implementing a patent box. Based on

[39]The data section gives a more technical explanation on how these variables are created.

the hypothesis, it would be expected to see positive coefficients for Z_{rst}, Y_{rst} and X_{rst}. Due to the way the data is organised (by region and sector), it is more difficult to determine the possible magnitude of the coefficients. However, if the estimates from Bradley et al. (2015) are used, multiplying their coefficient with the average amount of patent applications in each Dutch region and sector this would yield a coefficient of approximately 9.5 patent applications more per region and sector. Howerver, it should be noted that this is a very rough prediction since the trends of control groups are not taken into account.[40] Based on the theorertical model developped, it would be fair to say that both domestic and foreign invention contributions roughly share this 9.5 more patent applications equally.

Furthermore, several relevant control variables are added such that important determinants of R&D and patents are included. First, T_{jt} gives the statutory corporate income tax rate for country j for the year t, since this has an important negative effect on the attractiveness of the country regarding corporte profits.[41] η_{rt} is a set of economic and demographic indicators for region r at year t, which include GDP per capita and the sizes of each region with respect to GDP and population. It is expected that GDP and population affect patent applications positvely, although the relationship is not completely clear.[42] To control for the quality of the patents, λ_{rst} is a set of average quality indicators patents in region r for sector s and year t, see section 4.1 on the importance of these quality indicators. γ_t is a set of year dummies to control for time trends. The standard errors are clustered on country level, such that $\epsilon_{rst} = \nu_{jt} + \upsilon_{rst}$. Here ν_{jt} represents a random component specific to country j and υ_{rst} is the regional and sectoral residual.

5.2 Fixed effects estimation

Given that the differences-in-differences estimation method is prone to various difficulties (e.g. serial correlation, strict assumptions), and therefore has its limitations (Bertrand et al., 2004; Angrist & Pischke, 2008), using another estimation method as well would create a better view on the effects of the patent box. Since the data is constructed as panel data, a fixed effects estimation would be possible and thus contributive to the interpretation of the results of the

[40] The average amount of patent applications per region and sector in the Netherlands up to and including 2006 is 21.14. Multiplying this with the coefficient of 3% increase in patent applications for each percentage lowered on the tax for royalty income ($25 - 10 \times 0.03 = 0.45$) gives approximately 9.5 more patent applications per region and sector.

[41] See e.g. Dharmapala (2014) on how the corporate tax rate affects corporate profits.

[42] See for example table 5 in Alstadsæter et al. (2018), where no clear relationship appears to be between patent registrations and GDP level.

study.[43] The baseline equation for the fixed effects estimation is given by

$$\Omega = \beta_1 D_{jt} + \beta_2 T_{jt} + \beta_3 \tau_{jt} + \eta_{rt} + \lambda_{rst} + \gamma_t + \epsilon_{rst}, \tag{5.3}$$

where D_{jt} again denotes the treatment variable as in equation 5.2. All the other variables convey a similar meaning as in the differences-in-differences estimation. Again, standard errors are clustered on country level. Since there has been a change in the tax rate for royalty income in 2010, a control for this tax rate τ_{jt} is added besides the already existing controls used in the differences-in-differences estimation.[44] The fixed effects estimation should better account for regional differences, cancelling out the unobserved characteristics of each region through differencing via the within estimator. Due to the multiple observations for each region, the omitted variable bias should be taken out. To find the causal effect of a patent box via the fixed effects method, there should be no unobservable factors that are time-variant. This is similar to the common trend assumption that is essential for the differences-in-differences estimation.

5.3 Robustness analysis

To examine for robustness of the estimates, the previously mentioned analytical approach will be applied to Norway, instead of Austria. It will be essential to see whether the effects will change, given that the amount of patents applied for are substantially lower in Norway. Next to the lower amount of patents, Norway differs slightly on several other characteristics, such that this could impact the results.

Besides replicating the research with another control group, the research will also be replicated with another reference date for the patent applications. This to have a better view on whether selecting priority or application year makes a large difference. It could be that firms may use the difference between the priority and application in their advantage for tax reasons, as postponing the official application could lead to a preferential tax treatment of royalty income.

Given that the amounts of patent applications greatly differ per region, the regressions will be done again without using the three areas with most MNC activity in the Netherlands to eliminate the impact of MNCs and profit shifting. The regions Greater Amsterdam, Greater Rijnmond (Rotterdam), and – especially – Southeast Brabant (Eindhoven) are of major importance for the total amounts of patent applications in the Netherlands. This may be explained as Amsterdam attracts many multinationals from around the world, Rotterdam is known for its industry and

[43] First, a robust Hausman is applied to test both a fixed effects and random effects estimation equation. Since the result of this test made clear that $p < 0.05$, the fixed effects method is recommended to use instead of a random effects method.

[44] See section 2 on the implementation of the patent box in the Netherlands.

international port, and the region around Eindhoven claims to the Europe's leading innovative top technology region.[45] By excluding these regions, one could try to reduce the effect of profit shifting on the estimates and find the real effect of the patent box on innovation by ordinary firms.

A final robustness check is done by using the full pre-treatment period, instead of the reduced sample as explained in section 6.1. Due to complications with the common trend, it is undesirable to use the full pre-treatment period. Nevertheless, it might be valuable to see how the coefficients change if one uses all the years prior to treatment.

5.4 Selection of control group

To identify the true causal effect of the implementation of a patent box, it is essential to have an area as control group where no patent box has been implemented yet. Besides, this area should not be a tax haven, conduit country or conduct in any other shady tax practices relevant for this study. Ideally, this area has a constant corporate income tax rate over the period of interest, such that changes in this rate cause no difficulties in estimating the causal effect of the patent box on the actual levels of inventions in the Netherlands. Although one can control for such changes, it would be optimal if such changes would be mostly absent.

It may be obvious that selecting a control group - in this case a country - is relatively difficult since there is only a small group of candidates. To sum up some criteria; the country must be about the same size (economically, geographically and demographically), a member of the European Economic Area (EEA), be no tax haven or conduit country with respect to corporations, and have had no major changes in the corporate income tax rate in the period of interest. This brings the list of candidates down to Austria and Norway.

Table 2 shows certain relevant variables for both Austria and Norway in comparison to the Netherands. As can be observed from the table, there is no obvious candidate to be selected as control group. Austria resembles the Netherlands more closely based on population and the corporate tax rate, while Norway has more similarities concerning government size and gross domestic spending on R&D. Looking at the amount of patent applications made prior to 2007, both Austria and Norway seem to have far less patent applications than the Netherlands. There is only one criteria that still needs to be discussed, which are tax haven characteristics.

Can Austria be considered a Tax Haven? The financial and tax characteristics of Austria need to be carefully analysed so that there is a clear view whether Austria meets the tax haven

[45] This is mentioned at the website of Brainport Eindhoven, which is a cooperation of several technology-driven multinationals in the region of Eindhoven.

Table 2: Background characteristics (2006)

	The Netherlands	Control group: Austria	Control group: Norway
GDP (millions)[a]	733,955.3	297,154.7	274,835.2
GDP per capita[a]	40,964.6	31,619.9	54,091.4
Population (millions)	16.3	8.2	4.7
Land surface (km^2)	41,453	83,871	323,787
Corporate tax rate (%)	25	25	28
Government spending[b]	43	50.4	41.2
Gross domestic spending on R&D[b]	1.7	2.4	1.5
Inward FDI[b]	1.9	1.5	3
Patent applications	4,108	1,293	404

Notes: [a] Current prices, USD (constant exchange rate), [b] % of GDP. All data is retrieved from the OECD, except for the amount of patent applications. Data on the amount of patent applications is from the OECD REGPAT Database, which is used for the empirical analysis.

requirements. According to the OECD (1998), the following characteristics determine a country to be a tax haven: low or no taxes (corporate), lack of cooperation in information exchange, lack of transparency, no requisites on substantial acitivity.

Looking at these criteria, the EY tax guide reports that Austria currently has a 25% tax rate on corporate income, and has been around this value for the period of interest (Ernst & Young, 2019). However, Austria is ranked high on the Financial Secrecy Index, which is a list published by the Tax Justice Network. According to this index, they conduct the most comprehensive assessment on financial secrecy and the results it will have on global financial flows (Tax Justice Network, 2020). They mention that Austrian banks have been involved into several shady cases in the past, but are currently improving on their transparency. Nevertheless, there are still a few fields on which the Austrian authorities refuse to communicate openly, such as recorded company ownership, wealth ownership, and tax court secrecy. On the other hand, Austria does score well in several areas such as automatic information exchange, bilateral treaties, and international legal cooperation. To summarise, Austria unquestionably does not have an optimal track record regarding the transparecy of its tax policy, but this issue seems to cover private purposes. Looking at corporate taxation, they seem to be fairly transparent and thus suffice as a control group for this analysis nonetheless. Moreover, since they are not represented on tax haven lists such as the ones compiled by for example Hines Jr (2010) and Tørsløv et al. (2020) it is safe to assume that selecting Austria will be no threat to the study based on tax haven criteria.[46]

[46] Hines Jr (2010) labels a country as tax haven based on capital flows (gross flows of portfolio investment) in comparison to population, country size and GDP. Tørsløv et al. (2020) uses the list of Hines Jr & Rice (1994), thereby including Belgium and the Netherlands as well. Belgium is considered as tax haven because of deductibility of notional interest on equity and the Netherlands because of the low effective tax rate that US MNCs paid.

Can Norway be considered a Tax Haven? The case is much more simplified for Norway. Looking at the Financial Secrecy Index, Norway seems to be relatively open and is very sparingly engaged in questionable tax practices (Tax Justice Network, 2020).[47] The Norwegian corporate tax rate has been 28% up to 2013 and was slightly decreased to 27% in 2014 (Ernst & Young, 2019).

To conclude, both the tax haven characteristics of Austria and Norway form no threat to the investigation of the functioning of the patent box in the Netherlands. Given that both countries are compatible in numerous aspects, there is no obvious candidate that stands out and both countries suit as control group. However, looking at table 2, Austria appears to be the most optimal choice as the level of annual patent applications is drastically lower in Norway. This could affect the results possibly. Within differences-in-differences estimations, it is vital to look at differences caused over time. With an annual amount of patent applications as low as Norway, these differences can be minor compared to a country with many patent applications, such as the Netherlands. As a consequence, the results can be harmed. In the light of this, Austria will be used as first control group and Norway will be used as control group for the robustness analysis.

6 Results

6.1 Common trend assumption

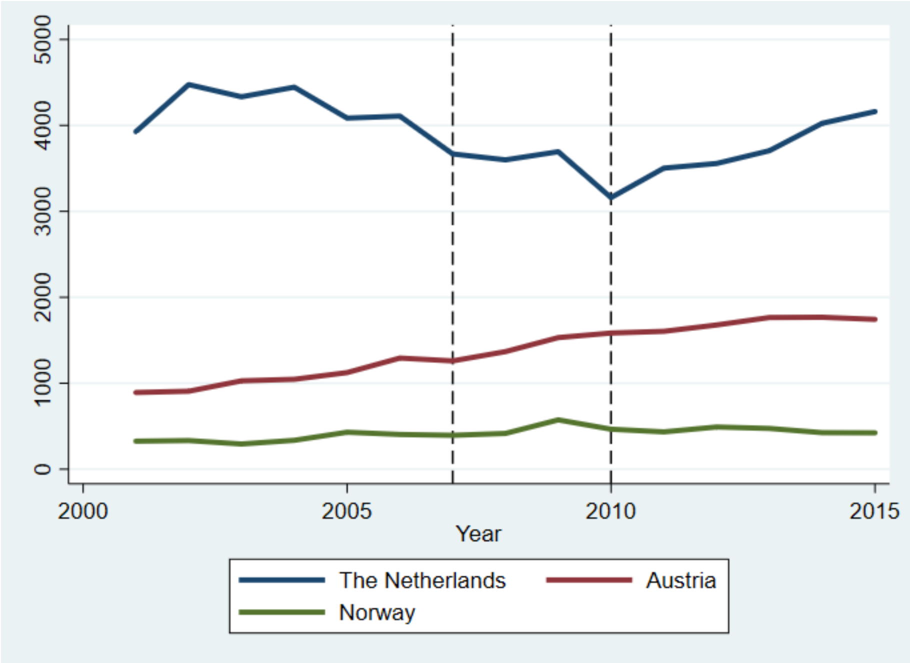
For the results to be of importance, it needs be ensured that the identifying assumption of the estimation method holds. That is, patent application trends would have been the same between treatment and control group in the absense of treatment, which in this case refers to implementation of the patent box. To test this assumption, both an informal and formal test are used. Looking at the trend lines within figure 1[48], the trend of the Netherlands follows a different line compared to Austria and Norway. This is foreboding and thus a more formal test is needed to assess whether the common trend assumption is violated. To test this, multiple leads and lags need to be included[49], as explained by Pischke (2005). In an ideal experimental setting, treatment has a signficant effect on the treatment group after the implementation of the policy rule. By including leads and lags in the baseline specification, one can identify whether these significant effects are only found after the implementation. Since several amendments are

[47] Norway seems to have some specific tax regimes for the shipping industry, as this industry is considered important to the Norwegian economy, but these regimes form no threat to the study.

[48] The two dashed lines represent the implementation of the patent box in 2007 and the major change to the patent box in 2010.

[49] Leads and lags are basically treatment variables that are simulated for a different time period. Leads are dummies prior to implementation, lags are dummies after implementation.

Figure 1: Patent applications by country (2001–2015)



made to the patent box after implementation, the leads are of main interest (dummy variables prior to implementation). In theory, the coefficients on the test dummies should be insignificant prior to the implementation year of the patent box. The results for both Austria and Norway as control groups can be found in table 3. Unfortunately, non-zero significant coefficients are found prior to 2007. However, since these coefficients are found in 2003 for Austria, and 2002 for Norway, the common trend assumption holds if the analysis is done from 2004 onwards. Hence, the true causal effect of the patent box can be found as long as the years before 2004 are excluded. One may questions why the trend lines in figure 1 look very different and yet, in the formal test no significant coefficients are found from 2004 onwards. This could be explained by the fact that the trend lines in the figure are based on national data, while the formal common trend uses the regional and sectoral data.

6.2 Effect of the patent box on the amount of applications

In table 4, we find the results on the amount of applications made after the implementation of the patent box. Here, *Patent box active* is the variable of interest. By using both lagged and unlagged effects, a statistically significant negative coefficient can be seen.[50] This indicates that the patent box actually leads to less patent applications, even if controls for fluctuations in economic growth are added.[51] Including patent quality indicators, the effect found in column

[50] As the data is organised by region and by sector, the coefficients need to interpreted as the average effect per sector within a region.

[51] This is done by including the control *log GDP per capita*.

Table 3: Common trend test on the amount of patent applications (2001–2015)

Control group	Austria	Norway
	(1)	(2)
Patent box regime	12.175	2.569
	(2.161)	(19.408)
Patent box active 2002	3.361	4.834***
	(0.550)	(0.043)
Patent box active 2003	-1.656**	-0.921
	(0.111)	(0.544)
Patent box active 2004	1.733	0.229
	(0.877)	(0.816)
Patent box active 2005	-3.037	5.278
	(3.033)	(2.256)
Patent box active 2006	-0.628	4.871
	(1.042)	(1.328)
Patent box active 2007	-1.793	11.362
	(1.624)	(3.233)
Constant	-372.636	-511.459*
	(242.760)	(70.804)
Observations	5,625	4,425
R-squared	0.068	0.055

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. Both estimations are done with the amount of patent applications as dependent variable. Estimation (1) uses Austria as control group, estimation (2) uses Norway as control group. Heteroskedasticity clustered standard errors adjusted on country level are in parentheses. Sector dummies and year dummies are included for both estimations. Test dummies for the years 2008-2015 are left out as those dummies prior to 2007 are of importance. Test dummy *Patent box active 2001* is taken out due to collinearity.

(6) implies that the patent box on average leads to 6.2 less patent applications per sector within each region. The difference between estimations with lagged effects and without lagged effects is not substantial, yet the magnitude of several coefficients is somewhat larger assuming lagged effects.[52]

Table 4: Differences-in-differences estimation on the amount of patent applications (2004–2009)

	Without lagged effect			With lagged effect		
	(1)	(2)	(3)	(4)	(5)	(6)
Patent box regime	16.428***	13.591**	16.088***	16.428***	13.470*	16.097***
	(0.000)	(0.963)	(0.086)	(0.000)	(1.089)	(0.162)
Patent box active	-5.905***	-5.877***	-5.977**	-6.300***	-5.803**	-6.227***
	(0.000)	(0.021)	(0.111)	(0.000)	(0.176)	(0.026)
Corporate tax rate	-37.060***	-51.244**	-45.626*	-37.060***	-53.546*	-47.342*
	(0.000)	(3.523)	(5.085)	(0.000)	(6.475)	(6.453)
Log GDP per capita			33.928			34.153
			(22.351)			(21.589)
GDP share			-6.761			-7.427
			(4.495)			(4.686)
Population share			12.030			12.977
			(7.199)			(7.500)
Family size		1.779	0.892		2.011	1.059
		(0.460)	(0.445)		(0.748)	(0.589)
Claims		0.505	-0.035		0.497	-0.039
		(0.321)	(0.016)		(0.325)	(0.028)
Forward citations		1.169	0.625		1.010	0.442
		(0.619)	(0.927)		(1.055)	(1.215)
Constant	24.426	20.138	-348.035	25.195	21.482	-350.114
	(6.673)	(4.973)	(235.579)	(7.422)	(6.341)	(227.183)
Observations	1,875	1,875	1,875	1,500	1,500	1,500
R-squared	0.016	0.032	0.072	0.015	0.031	0.067

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. All estimations are done with the amount of patent applications as dependent variable. Austria is used as control group. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. In estimations (4) to (6) the year 2007 is excluded to take the lagged effects of R&D into account. Sector dummies and year dummies are included for all estimations.

Looking at other control variables, a negative coefficient can be seen for the corporate tax rate, indicating that a lower corporate tax rate leads to more patent applications. Altough it should be taken into account that due to the presence of the (lower) tax rate on patent income and several other tax rules on stimulating innovation, the initial effect of the corporate tax is blurred and is thus difficult to separate in this context. The coefficients related to the patent quality indicators such as family size, claims, and forward citations should be seen more as correlations rather than effects. Looking at table 4, higher patent quality is associated

[52] There have been done estimations with and without including anticipatory effects as well. The difference was only small between estimations, such that is decided to focus mainly on the difference in presence of lagged effects.

with more patent applications, nevertheless these coefficients are not significant. The regional characteristics tell us that a 1 percent increase in the GDP per capita is related to approximately 34 more patent applications, and a 0.01 percent point increase in GDP share is associated with 7 lower patent applications. This is noteworthy as it would be expected to see a positive coefficient for this variable. When a region has a higher GDP share compared to other regions, you would expect this region to have more firm activity and therefore probably more R&D as well. As expected, this relationship does hold for the variable population share. Unfortunately, these three coefficients are insignificant.

Table 5: Differences-in-differences estimation on invention contributions (2004–2009)

	Domestic invention contribution			Foreign invention contribution		
	(1)	(2)	(3)	(4)	(5)	(6)
Patent box regime	9.605***	7.562**	9.494***	6.823***	5.908*	6.603***
	(0.000)	(0.555)	(0.071)	(0.000)	(0.534)	(0.091)
Patent box active	-3.642***	-3.276**	-3.592***	-2.658***	-2.527**	-2.636***
	(0.000)	(0.102)	(0.020)	(0.000)	(0.074)	(0.006)
Corporate tax rate	-22.902***	-32.663**	-28.363*	-14.158***	-20.883	-18.979
	(0.000)	(2.411)	(3.053)	(0.000)	(4.064)	(3.399)
Log GDP per capita			25.796			8.357
			(14.424)			(7.165)
GDP share			-6.592			-0.835
			(4.055)			(0.631)
Population share			10.841			2.136
			(5.886)			(1.615)
Family size		1.234	0.560		0.776	0.499
		(0.294)	(0.266)		(0.454)	(0.324)
Claims		0.400	0.002		0.097	-0.042**
		(0.211)	(0.025)		(0.114)	(0.003)
Forward citations		0.631	0.238		0.379	0.204
		(0.706)	(0.739)		(0.348)	(0.476)
Constant	16.663	13.475	-267.414	8.532	8.007	-82.700
	(4.487)	(3.650)	(152.348)	(2.935)	(2.690)	(74.835)
Observations	1,500	1,500	1,500	1,500	1,500	1,500
R-squared	0.014	0.032	0.079	0.019	0.031	0.052

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. Estimations (1) to (3) are done with the domestic invention contribution as dependent variable, while estimations (4) to (6) are estimated on the foreign invention contribution. Austria is used as control group. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. The year 2007 is excluded to take the lagged effects of R&D into account. Sector dummies and year dummies are included for all estimations.

6.3 Domestic or foreign inventions?

Since the results found in the previous section indicate that the patent box caused less patent applications in the Netherlands, it is important to know whether it is caused by domestic or foreign inventions. Returning to the findings from the theoretical framework developed in section 3, a patent box should cause both more domestic innovation and more foreign innovation. Foreign innovations patented in the Netherlands could resemble profit shifting in this context, since the most important reason for a firm to patent an invention in the Netherlands is the tax climate. By using foreign contributions to Dutch patents as proxy, one can measure the size of profit shifting via a patent box. Since a negative effect is found in table 4, negative coefficients for domestic invention and foreign invention are expected as well.

Table 5 shows the results for the differences-in-differences estimation on the domestic and foreign invention contributions using a lagged effect.[53] It is found that both domestic and foreign invention contributions have gone down, where all coefficients of interest are statistically significant. All other variables show approximately the same behaviour as seen in table 4, although the magnitude of the coefficients has changed slightly. The relevance of the economic size of the region seems to be diminished substantially under the foreign invention share.[54] Nevertheless, these controls are statistically insignificant. Moreover, the coefficient of interest – patent box active – is relatively consistent between the different estimations, hence it is possible to say that both variables move in the same direction.

6.4 Sectoral differences

Considering that the dataset distinguishes patent applications per sector, it is possible to find out whether the decreases in patent applications found in tables 4 & 5 are also present in all the various sectors, or whether there are sizeable differences between the sectors of technology. To test this, the baseline estimation as described in equation (5.2) is used for each sector, regressing on the amount of patent applications, the domestic invention contribution, and the foreign invention contribution. The results of the estimation can be found in table 6.

Within table 6, we find that in all sectors the amount of applications has decreased on average (albeit only three coefficients are significant) using lagged effects. The coefficients do differ moderately between sectors, but one should take into account that there are large differences between sectors in the amount of patent applications that are being done, as can be seen in figure C.1 in the appendix. Hence, on average we detect no surprising results here with respect to the findings found in table 4.

Proceeding to table B.4, there seem to be no substantial differences compared to the findings in table 6. The effect is clear within the sector electrical engineering, with a strong negative coefficient. For the sector instruments, a (insignificant) positive coefficient can be found. In

[53] The same regression without lagged effect can be found in table B.3.

[54] This makes perfectly sense as the economic size of an area in the Netherlands should have no impact on the amount of inventions that are made abroad. Still, correlations are found for the log of GDP per capita.

Table 6: Sectoral differences-in-differences estimation on the amount of patent applications (2004–2009)

	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields
	(1)	(2)	(3)	(4)	(5)
Patent box regime	43.106***	14.116**	19.650**	5.180	0.799
	(0.192)	(0.408)	(1.177)	(1.092)	(0.261)
Patent box active	-22.929**	-0.627	-3.763*	-2.112	-0.329**
	(1.288)	(0.271)	(0.511)	(0.500)	(0.014)
Corporate tax rate	-238.029*	-16.558**	17.192	-28.958**	-15.605*
	(34.564)	(0.357)	(4.207)	(1.514)	(2.097)
Log GDP per capita	69.340	37.907	33.961	25.349*	9.764*
	(55.476)	(25.722)	(27.204)	(3.032)	(1.463)
GDP share	-18.106	-8.429	-4.989	-4.398	-1.864**
	(11.939)	(5.488)	(5.746)	(2.125)	(0.134)
Population share	27.182	13.571	11.806	8.821	4.060*
	(18.257)	(8.643)	(8.213)	(3.868)	(0.526)
Family size	3.785	0.943	0.411	0.471	0.364**
	(2.679)	(0.497)	(0.230)	(0.133)	(0.016)
Claims	-0.160	0.041	-0.648	0.055	0.096**
	(0.205)	(0.014)	(0.182)	(0.068)	(0.004)
Forward citations	-3.800	-0.783	5.585	0.209	0.906
	(4.407)	(0.648)	(3.144)	(0.712)	(0.721)
Constant	-680.436	-407.943	-377.278	-262.004*	-100.951
	(595.501)	(281.459)	(293.768)	(36.018)	(17.711)
Observations	300	300	300	300	300
R-squared	0.051	0.079	0.423	0.537	0.368

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. All estimations are done with the amount of patent applications as dependent variable. Austria is used as control group. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. The year 2007 is excluded to take the lagged effects of R&D into account. Year dummies are included for all estimations. Further information on the sectors can be found in table B.2.

the other fields, a very small positive coefficient is present. Table B.5 shows the results for the foreign invention contribution. Here we see a decline in all sectors, where four out of five coefficients show significance.

Bringing all the the sectoral differences together, the findings are approximately in line with the findings found in tables 4 and 5. The biggest changes took place within electrical engineering, but this is no suprise as the most patent applications are made in this sector in the Netherlands. Given that there are no sizable differences between the sectors, the implementation of the patent box did not benefit one sector more than others.

6.5 Effect of the 2010 changes on the amount of applications

It may be clear from section 2 that the design of the patent box (octrooibox) was far from optimal to have a profound impact on the levels of R&D in the Netherlands, since the the tax rule was too complicated and too narrowly defined. The concept of the innovatiebox surpassed many of these limitations. In combination with the 5% point rate decrease it has way more potential to become a succesful tax rule compared to the patent box in its previous form. To test whether this actually has been the case, the regional analysis of section 6.2 and 6.3 is repeated for the implementation of the innovatiebox.

Table 7 gives the results of the differences-in-differences estimation on the amount of patent applications. Including all controls, the implementation of the innovatiebox has had a negative effect on the amount of patent applications made with approximately 2.6 applications within each sector per region. Remarkably, the coefficients are positive assuming lagged effects. Unfortunately, these coefficients are both not statistically significant. With respect to the other estimations made in table 4 and 5, the coefficient for the corporate income tax rate has changed drastically. This could be due to the fact that there has been less variation in the corporate tax rate,[55], and therefore could have impacted the estimation more. Although the direction of the coefficients seems to make sense, the argument mentioned in section 6.2 still holds that the effect might be difficult to seperate due to the presence of other relevant tax rules on innovation.[56] The magnitude of the corporate tax rate therefore seems to be overestimated. The coefficients on the log of GDP per capita, GDP share, and population show the same behaviour as found for the octrooibox, but only smaller in size (except for the log of GDP per capita which held the same magnitude). These coefficients are nevertheless insignificant.

[55] Both Austria and the Netherlands had similar corporate tax rates around these years. That is the reason why the corporate tax rate is taken out by STATA in estimations (4) to (6).

[56] Say that one wants to measure the effect of the corporate tax rate on profit shifting. Measuring this effect would be easier if there would be no exemptive tax rules or tax holidays. If these tax rules are present, finding the real effect of the corporate tax rate would become more difficult as it is blurred by effects of other tax rules.

Table 7: Differences-in-differences estimation on the amount of patent applications (2007–2015)

	Without lagged effect			With lagged effect		
	(1)	(2)	(3)	(4)	(5)	(6)
Patent box regime	13.111***	9.374*	13.534***	10.652***	6.551	9.587*
	(0.000)	(1.004)	(0.183)	(0.000)	(1.141)	(0.890)
Patent box active	-3.948***	-1.810	-2.570	-1.489***	0.986	1.409
	(0.000)	(0.502)	(0.656)	(0.000)	(0.617)	(1.767)
Corporate tax rate	-491.800***	-566.488**	-787.845			
	(0.000)	(15.388)	(199.741)			
Log GDP per capita			30.856			32.045
			(22.718)			(24.012)
GDP share			-2.361			-2.577
			(3.000)			(3.158)
Population share			6.822			7.083
			(4.420)			(4.607)
Family size		1.194	0.410		1.157	0.408
		(0.480)	(0.395)		(0.508)	(0.436)
Claims		0.984	0.270**		1.017	0.279***
		(0.282)	(0.011)		(0.292)	(0.001)
Forward citations		2.000	0.929		1.758	0.696
		(0.639)	(0.750)		(0.618)	(0.695)
Constant	133.240**	140.784**	-137.339	10.328	-0.828	-346.985
	(3.244)	(4.801)	(193.022)	(3.097)	(0.634)	(256.973)
Observations	3,000	3,000	3,000	2,625	2,625	2,625
R-squared	0.016	0.046	0.125	0.016	0.045	0.123

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. All estimations are done with the amount of patent applications as dependent variable. Austria is used as control group. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. The year 2009 is excluded to prevent from having anticipatory effects in the estimations. In estimations (4) to (6) the year 2010 is excluded to take the lagged effects of R&D into account. Coefficients on the corporate tax rate cannot be estimated in estimations (4) to (6) because of not enough variation in the values. Sector dummies and year dummies are included for all estimations.

Table 8: Differences-in-differences estimation on invention contributions (2007–2015)

	Domestic invention contribution			Foreign invention contribution		
	(1)	(2)	(3)	(4)	(5)	(6)
Patent box regime	6.247***	3.133	5.451*	4.405***	3.418*	4.136**
	(0.000)	(0.734)	(0.733)	(0.000)	(0.407)	(0.158)
Patent box active	-0.205***	1.652	2.116	-1.284***	-0.666	-0.707
	(0.000)	(0.387)	(1.335)	(0.000)	(0.230)	(0.432)
Corporate tax rate			26.592			5.454
			(17.928)			(6.084)
Log GDP per capita			-3.801			1.224*
			(3.053)			(0.104)
GDP share			7.540			-0.457
			(4.023)			(0.583)
Population share		0.846	0.295		0.312	0.113
		(0.317)	(0.323)		(0.191)	(0.113)
Family size		0.801	0.219***		0.216	0.060**
		(0.200)	(0.001)		(0.092)	(0.002)
Claims		1.174	0.386		0.584	0.311
		(0.484)	(0.450)		(0.134)	(0.245)
Forward citations	8.161	-0.372	-288.053	2.167	-0.456	-58.932
	(1.921)	(0.378)	(191.976)	(1.176)	(0.256)	(64.997)
Observations	2,625	2,625	2,625	2,625	2,625	2,625
R-squared	0.012	0.041	0.113	0.030	0.048	0.118

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. Estimations (1) to (3) are done with the domestic invention contribution as dependent variable, while estimations (4) to (6) are estimated on the foreign invention contribution. Austria is used as control group. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. The year 2009 is excluded to prevent from having anticipatory effects in the estimations. The year 2010 is excluded to take the lagged effects of R&D into account. Coefficients on the corporate tax rate cannot be estimated in estimations (4) to (6) because of not enough variation in the values. Sector dummies and year dummies are included for all estimations.

Table 8 dives a bit deeper into the patent applications and differentiates on the origin of the invention, using lagged effects as in table 7. It can be seen that there are no large differences between the domestic and foreign contribution of the invention. Although the coefficients are statistically insignificant, the domestic invention contribution shows an increase due to the implemenation of the patent box, while the foreign invention contribution shows a moderate decline. This is slightly suprising, as one would have expected to see more foreign innovations patented in the Netherlands as well. The results on the domestic and invention contribution are not in line with the predictions of the theoretical framework, as laid out in section 3. In the theoretical framework it is found that a patent box should create more innovation but lead to more profit shifting as well. If it appears that the patent box has caused more patent applications, this should be reflected partly in the domestic contribution and partly in the foreign contribution to inventions. This is not what is found in table 8 since the coefficients do not move in the same direction. Again, it has to be mentioned that these coefficients are not significant.

6.6 Fixed effects estimation

Given that the results found above are not in line with the predictions of the theoretical model, it may be wise to do a fixed effects estimation as well, including the complete sample period and a reduced sample. Herein, the tax rate on royalty income is included as well to control for the differences between the octrooibox and innovatiebox. It is not possible to control for any other differences, since it is hard to transform this into numbers and thus will be prone to errors. Equation (5.3) is used to estimate the effect of the patent box on the amount of patent applications, the domestic contribution, and the foreign contribution of the inventions.

Table 9 gives the results of the fixed effects estimation. The results are fairly in line with the differences-in-differences estimation done earlier in tables 4 and 5. On average, a signficant coefficient of -8.9 is found for the patent box. The coefficients on the domestic and foreign invention contributions are both negative as well, implying that the implementation of the patent box did not create more innovation in the sense of more patent activity, both domestically and foreign. Remarkably, in several of the estimations the tax rate on royalty income (*Patent box rate*) has a positive coefficient for the domestic invention share, indicating that a 1 percent point increase of the tax rate has a positive effect on the amounts of innovation done. One possible explanation could be that multinationals care less about the height of the rate, but more about the presence of a patent box. However, this would also imply the coefficients should be statistically insignificant. This is only the case for estimation (5), though this coefficient is negative. It might eventually be due a statistical cause. In the sample, on average the corporate tax rate decreases for all three countries. Together with the negative results found for the dependent variables, it might be plausible that the coefficient for the tax rate for royalty income becomes positive.[57] The coefficient for the corporate tax rate does behave according to expectations.

Low R-squared As may have been clear from the various estimations in this section, many of them report a low R-squared, especially the fixed effects estimations. The sections on the data description and empirical strategy have explained that in this thesis the analysis takes a regional and sectoral perspective, while many other studies on patents take the perspective of the firm. This is an important difference that has impact on the way a model needs to be formulated, i.e. different control variables are needed. This thesis has therefore more reliance on regional variables and characteristics, which make it more difficult to control for the environment in which the firm decides to innovate or not. Moreover, when the environment is narrowed, as is done in section 6.4, the R-squared increases. In these situations the model has a better fit compared to the complete environment including all section. All in all, the low R-squared is not optimal, but it also forms no real threat to the thesis.

[57] Another possible explanation could be that this coefficient is prone to errors since the variable is only available for the Netherlands (since neither Austria or Norway has a patent box), and has values equal to 0 for Austria and Norway. However, replacing these 0 values by the regular corporate tax rate gives a positive coefficient as well. Hence it is difficult to determine what causes this positive coefficient.

Table 9: Fixed effects estimation (2001–2015)

	Full sample			Sample excluding 2003 and earlier		
	Patent applications	Domestic contribution	Foreign contribution	Patent applications	Domestic contribution	Foreign contribution
	(1)	(2)	(3)	(4)	(5)	(6)
Patent box active	-10.176**	-5.021**	-5.155**	-8.869**	-3.119	-5.750**
	(0.243)	(0.113)	(0.356)	(0.225)	(0.579)	(0.354)
Corporate tax rate	-38.824**	-37.204***	-1.620	-43.562***	-29.401***	-14.161**
	(1.361)	(0.012)	(1.373)	(0.659)	(0.227)	(0.433)
Patent box rate	43.217**	8.588*	34.629*	27.850*	-5.265	33.116*
	(1.933)	(0.865)	(2.799)	(2.343)	(5.650)	(3.307)
Log GDP per capita	-10.483	-0.961	-9.523	3.876	10.994	-7.118
	(2.915)	(0.344)	(3.259)	(2.480)	(5.822)	(3.341)
GDP share	-10.781	-3.170	-7.610	-4.924**	0.847	-5.771
	(2.837)	(0.665)	(3.502)	(0.190)	(2.820)	(2.630)
Population share	18.350*	15.202	3.148	24.180	19.580	4.600*
	(2.180)	(3.158)	(0.978)	(8.293)	(8.909)	(0.616)
Family size	-0.253	-0.165	-0.088	-0.079	-0.013	-0.066
	(0.049)	(0.030)	(0.020)	(0.223)	(0.093)	(0.130)
Claims	0.087*	0.076*	0.011**	0.108*	0.101	0.007
	(0.009)	(0.010)	(0.001)	(0.013)	(0.017)	(0.004)
Forward citations	0.204	0.132	0.072	0.116	0.056	0.060
	(0.122)	(0.043)	(0.079)	(0.033)	(0.040)	(0.073)
Constant	115.042	0.385	114.657	-64.374**	-151.575	87.201
	(43.456)	(3.528)	(39.928)	(4.611)	(45.320)	(40.709)
Observations	5,250	5,250	5,250	4,125	4,125	4,125
R-squared	0.013	0.009	0.019	0.016	0.018	0.016
Number of units	375	375	375	375	375	375

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.3) is used to estimate the different coefficients. Estimations (1) and (4) are done on the amount of patent applications, estimations (2) and (5) are done on the domestic invention contribution, estimations (3) and (6) have the foreign invention contribution as dependent variable. The full sample period 2001-2015 is being used in estimations (1) to (3). A reduced sample is used in estimations (4) to (6), see subsection on the common trend assumption. Austria is used as control group. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. Sector dummies and year dummies are included for all estimations.

7 Robustness analysis

7.1 Estimations with Norway as control group

To see whether the results are robust, Norway is selected as control group. Based on the criteria mentioned in section 5.3, Norway would also make a viable control group. The estimations done in section 6.2 and 6.3 are replicated with Norway, instead of Austria, using baseline equation 5.2.[58]

Table 10: Differences-in-differences estimation with Norway as control group (2004–2009)

	Patent applications	Domestic invention contribution	Foreign invention contribution
	(1)	(2)	(3)
Patent box regime	20.530	14.949	5.581
	(17.304)	(13.353)	(3.951)
Patent box active	6.021**	3.723	2.298
	(0.394)	(0.995)	(0.601)
Corporate tax rate	148.969***	93.482**	55.487*
	(1.361)	(6.834)	(8.195)
Log GDP per capita	31.080	24.483	6.597
	(7.787)	(6.738)	(1.049)
GDP share	-0.674	-1.914	1.240**
	(3.355)	(3.378)	(0.023)
Population share	4.070	4.083	-0.013
	(7.237)	(5.919)	(1.318)
Family size	0.852	0.441	0.411
	(0.651)	(0.308)	(0.343)
Claims	0.075	0.101	-0.027
	(0.018)	(0.027)	(0.009)
Forward citations	0.106	0.029	0.076
	(0.963)	(0.572)	(0.392)
Constant	-382.043	-294.715	-87.328
	(105.050)	(85.733)	(19.317)
Observations	1,180	1,180	1,180
R-squared	0.055	0.058	0.053

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. Norway is used as control group. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. The year 2007 is excluded to take the lagged effects of R&D into account. Sector dummies and year dummies are included for all estimations.

Table 10 gives the results of estimating the differences-in-differences on the amount of patent applications, domestic invention contribution, and foreign invention contribution. The coefficients indicate that the patent box has created more patent applications and therefore more domestic and foreign innovation as well, although the last two coefficients appear to be insignificant. The coefficients for the corporate tax rate show positive values, which is surprising. All other variables show roughly similar behaviour to the estimations with Austria as control group.

[58] A fixed effects estimation is done as well. Table B.7 shows the results.

It should be kept in mind that the common trend assumption was only violated for Norway before 2003, such that this ensures the findings are valid.

The positive results for patent applications, domestic and foreign contribution with control group Norway makes one wonder why these findings are different compared to Austria. This can be explained by the fact that the trends of Austria and Norway are not completely the same, as can be seen in figure 1. Hence, this shows the dependence of the results on the common trend assumption. Apparently, within each region and sector, the patent box has had positive effects in comparison to Norway, but negative effects in comparison to Austria. To have more exact numbers on the functioning of the patent box, one needs to strive for finding an area with a trend more similar to the trend of the Netherlands. Unfortunately, this is easier said than done.

Table 11: Differences-in-differences estimation using the application year (2004–2009)

	Patent applications	Domestic invention contribution	Foreign invention contribution
	(1)	(2)	(3)
Patent box regime	14.843**	8.670**	6.172**
	(0.437)	(0.238)	(0.199)
Patent box active	-4.600***	-2.758***	-1.842**
	(0.029)	(0.002)	(0.031)
Corporate tax rate	12.203**	8.401**	3.803**
	(0.343)	(0.542)	(0.199)
Log GDP per capita	35.313	25.425	9.888
	(23.807)	(15.391)	(8.416)
GDP share	-7.818	-6.450	-1.367
	(5.049)	(4.144)	(0.906)
Population share	13.478	10.659	2.819
	(7.934)	(5.930)	(2.003)
Family size	1.211	0.700	0.511
	(0.754)	(0.386)	(0.368)
Claims	-0.097*	-0.033*	-0.064
	(0.012)	(0.004)	(0.016)
Forward citations	-0.088	-0.057	-0.030
	(1.790)	(1.083)	(0.707)
Constant	-137.595	-99.541	-38.054
	(86.742)	(56.090)	(30.651)
Observations	1,500	1,500	1,500
R-squared	0.059	0.068	0.047

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. Austria is used as control group. Instead of the priority date of each patent, the applications date of each patent is used as reference date. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. The year 2007 is excluded to take the lagged effects of R&D into account. Sector dummies and year dummies are included for all estimations.

7.2 Estimations using the application year as reference year

As discussed in section 4, there are two relevant dates for every patent application, and the priority date lies closest to the actual date of invention (Maraut et al., 2008). Nonetheless, for 82% of the patents in the sample, the application date is at least one year later than the priority date. For tax reasons, it can be argued that this difference between the priority date and application date can be used in favour of the firm (e.g. delaying the official application). It could thus be the case that the results are different when the year of the official application is used instead of the year of the priority date.

The results of these estimations can be found in table 11, using Austria as control group again. Compared to table 3, several coefficients changed in magnitude, but these differences are only small such that there is no huge difference between the two types of reference dates. Under both reference dates, a negative coefficient is found for the amount of patent applications (-4.6 compared to -6.2 in table 4, column (6)). Consequently, the magnitudes of the coefficients for the domestic and foreign invention contribution are smaller under the application date compared to the priority date. Hence, it can therefore be concluded that the results are robust since they are comparable under both reference dates.

7.3 Estimations excluding Amsterdam, Rotterdam & Eindhoven

Given the high skewness in the distribution of MNCs within regions within the Netherlands, it might be good to exclude several regions to have a more balanced distribution of MNCs between regions. Large multinationals such as Royal Philips generate an enormous amount of patents on a yearly basis, resulting in major regional differences in patent application numbers between the region of Eindhoven and more rural areas. The presence of many multinationals in an area can impact the results substantially since it is easier for these firms to engage in profit shifting via intellectual property, especially in comparison to small and medium sized firms.

Table 12 shows the results of the estimations excluding several important regions. Compared to table 3, the coefficients for the amount of patent applications, domestic invention contribution, and foreign invention contribution are smaller in magnitude, although for the latter the coefficient no significance is found. The findings are surprising since significant coefficients are found for the amount of applications and domestic invention contribution, implying that the implementation of the patent box has led MNCs to innovate less. The coefficient on the foreign invention contribution is insignificant, thus no real changes in profit shifting are found if the three most influential regions are excluded. Initially, it was expected that these regions would have a considerable positive impact on the amount profit shifting occurring in the Netherlands

Table 12: Differences-in-differences estimation excluding regions Amsterdam, Rotterdam & Eindhoven (2004-2009)

	Patent applications	Domestic invention share	Foreign invention share
	(1)	(2)	(3)
Patent box regime	4.586*	2.864*	1.723*
	(0.535)	(0.301)	(0.234)
Patent box active	-1.541**	-1.342**	-0.199
	(0.067)	(0.031)	(0.036)
Corporate tax rate	-4.112	-6.910*	2.798
	(0.801)	(0.640)	(1.441)
Log GDP per capita	16.389	12.383	4.006
	(9.530)	(5.594)	(3.936)
GDP share	-2.616	-1.404	-1.212
	(3.228)	(1.799)	(1.429)
Population share	6.004	3.756	2.248
	(4.587)	(2.546)	(2.041)
Family size	0.406***	0.215	0.191
	(0.001)	(0.095)	(0.097)
Claims	-0.056	0.035	-0.091
	(0.106)	(0.029)	(0.077)
Forward citations	1.614	1.005	0.609*
	(0.332)	(0.253)	(0.079)
Constant	-179.638	-133.105	-46.534
	(104.882)	(61.599)	(43.283)
Observations	1,440	1,440	1,440
R-squared	0.328	0.370	0.175

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. Austria is used as control group. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. The year 2007 is excluded to take the lagged effects of R&D into account. Sector dummies and year dummies are included for all estimations.

because of the large number of multinationals active in these regions. But if you take into account that several multinationals enjoy extremely low corporate tax rates in the Netherlands[59], would implementing a patent box have any effect on the behaviour of these multinationals? Generally, there are no large differences in the coefficients, although the standard errors have increased considerably.

Table 13: Differences-in-differences estimation using a longer pre-treatment period (2001–2009)

	Patent applications	Domestic invention contribution	Foreign invention contribution
	(1)	(2)	(3)
Patent box regime	14.625*	9.396*	5.229**
	(1.176)	(0.783)	(0.393)
Patent box active	-4.824	-3.457*	-1.367
	(0.803)	(0.529)	(0.274)
Corporate tax rate	-25.231*	-27.506*	2.275
	(3.860)	(3.282)	(0.578)
Log GDP per capita	36.191	27.511	8.680
	(21.922)	(15.289)	(6.633)
GDP share	-8.909	-7.816	-1.093
	(5.097)	(4.671)	(0.427)
Population share	14.915	12.527	2.388
	(8.203)	(6.788)	(1.415)
Family size	1.234	0.736	0.497
	(0.957)	(0.551)	(0.405)
Claims	-0.126	-0.064*	-0.062
	(0.035)	(0.006)	(0.029)
Forward citations	0.625	0.329	0.296
	(0.938)	(0.594)	(0.345)
Constant	-377.398	-283.131	-94.268
	(232.539)	(161.011)	(71.528)
Observations	2,625	2,625	2,625
R-squared	0.049	0.049	0.043

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. Austria is used as control group. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. The year 2007 is excluded to take the lagged effects of R&D into account. Sector dummies and year dummies are included for all estimations.

7.4 Full sample estimation

Since it is found that the common trend assumption is violated for Austria in 2003 and for Norway in 2002, it is also interesting to know how this would have impacted the estimations when using the full pre-treatment period, i.e. from 2001 on. The results can be found in table 13, where Austria is used as control group.[60] It immediately becomes evident that the coefficients

[59]For example, in 2019 CEO Hans de Jong of Philips Netherlands declared to the Second Chamber that Philips hardly payed any corporate taxes in the Netherlans for the last decade (*Belastingafdracht multinationals*, 2019). It was already known that Royal Dutch Shell did not pay corporate taxes at all for many years.

[60]An estimation with Norway as control group can be found in the appendix, table B.8.

on the variable of interest become insignificant, except for the estimation on the domestic invention contribution. The coefficients on the control variables do resemble the estimations with shortened pre-treatment periods. This robustness analysis again shows the importance of the common trend assumption in a differences-in-differences estimation.

In conclusion, concerning the robustness of the model, it is plausible to say that the coefficients of the variable of interest change when using alternative specifications, such as a different control group, application year, excluding several regions, or using the full sample period. These changes have partly to do with the different trends of Austria and Norway, i.e. it would have been uncommon if the coefficients would have stayed exactly the same using Norway as control group in this situation. The control variables change only slightly between the different estimations, indicating that they are well-placed within the model. Nevertheless, many of the control variables are insignificant. All in all, the robustness of the model does not seem optimal. However, if one leaves the sensitivity to different control groups out of scope, the robustness seems to be relatively satisfactory.

8 Discussion

In the empirical analysis, the predictions of the theoretical framework are not confirmed. Using a sample of EPO patent applications ranging from 2001 to 2015, no increased number of yearly patent applications is found in comparison with a country that did not implement a patent box. In the various estimations, a coefficient of approximately -6 is found. This indicates that the implementation of the patent box caused, on average, 6 patent applications less in each sector per region, ceteris paribus. Going further into detail, by seperating domestic inventions from foreign inventions, it is found that both the domestic invention contribution and foreign invention contribution have decreased after implementation. In relative measures, the amount of patent applications decreased with roughly 30%, domestic invention contribution decreased with 25% and the foreign invention contribution decreased with 43% in each region per sector.[61] This signals that neither domestic R&D spending nor profit shifting benefits from this tax rule. The results differ slightly per sector of technology, but not enough that a real difference is found between the different sectors.

Since several large changes have been made to the patent box, another round of estimations are done on the period after 2010. In spite of the 5% point rate drop on royalty income, the results are still negative. The same holds for the results of the fixed effects estimation, where

[61] Average amounts of patent applications, domestic and foreign invention contribution are 20.81, 14.69 and 6.11 respectively, over the period 2001–2006. Dividing the coefficients of table 3 and 4 by this value gives -29.7%, -24.5% and -43.2%.

the effect of the patent box is estimated over a large time frame, including the tax rate on royalty income. Again, it is found that the tax rule has not been effective since the fixed effects estimates 8 patent applications less per regions, for each sector.

The question one should ask is why the patent box did not cause more domestic and foreign innovation. Firstly, as can be read in section 2, the initial set up of the patent box (octrooibox) was – to put it lightly – weak. It had various difficulties (e.g. losses only deductible at low tax rate, complexity of the rule) which made the tax rule only appropriate for a small group of patent applicants. In 2010, the patent box got revised (innovatiebox) and its scope was widened to innovation in a broader sense, including general R&D as well. Secondly, although smaller negative results are present here too, it is wildly known that it takes time to invent technology and therefore the results should be more pronounced on the long-term. Albeit regressions were done with a one year lag, it could be that more lags are needed.[62] Thirdly, it may also be the case that the tax rules on innovation function better for the non-patent part of R&D, which is something that is not measured in this thesis.[63] Fourthly, since the Dutch patent box was one of the first patent boxes, it could be that general awareness was not that high around 2007. After a while, awareness increased as it became clear that patent boxes appeared to be a great opportunity for MNCs to engage in profit shifting. Fifthly, this study uses only patents filed at the EPO, while Bradley et al. (2015) report that only 17% of all European innovations are patented via the EPO. It could therefore be the case that the results differ considerably if the patent applications of the national patent offices would be included as well.[64] Lastly, it could be due to the selection of control group as well. While Austria is the main control group in this thesis, the results in the robustness analysis with Norway as control group give a completely different view of the patent box. This illustrates the importance of having a fitting control group. In the end, Austria is kept as main control group since it should resemble the Netherlands most optimally based on several economic and demographic characteristics and most importantly, the amount of annual patent applications (see table 2).

Nevertheless, taking the CPB report on digitalisation of R&D into account, the negative results are not that surprising. In this critical report it is mentioned that due to the growing importance of information technologies and data, the role of R&D in the production process has changed over time. Bijlsma & Overvest (2020) state that the role of closed innovation, i.e. protection of intellectual property, on the other hand, has become less important during

[62] Taking more lags could harm the results in this setting since it either reduces the period after implementation, or it overlaps with the second phase of the patent box in 2010. Therefore it is decided to keep it to one lag.

[63] An example would be the WBSO, which is the tax rule promoting general R&D, as discussed in section 2.

[64] In the end, this completely depends on the percentages of innovations that are being patented at the national offices for both the Netherlands and control groups. The 17% mentioned in Bradley et al. (2015) is a number for Europe as a whole and could vary heavily for each country.

the last decades. Currently, firms increasingly focus on open innovation via digital platforms[65] to gather more external knowlegde and spread this knowledge via these open platforms. This could additionaly possibly explain the findings of this thesis.

9 Conclusion

In the first decade of the 21st century many European countries, of which the Netherlands was one of the first, have implemented patent boxes as a means to improve their tax climate, utlimately targetting at more domestic R&D and attracting foreign direct investment. Given that there is no general consent on whether patent boxes increase domestic innovation, I asked the question *"To what extent did the introduction of the patent box create more R&D in the Netherlands?"* In the theoretical model developed in section 3, it is found that a patent box should trigger domestic R&D spending positively by taxing the royalty income at a lower rate than regular corporate income, leading to more innovation. Besides more innovation, the patent box should create incentives for profit shifting from abroad due to the favourable difference between the corporate tax rate and the tax rate on royalty income. In the empirical analysis these predictions, however, are not found and thus the hypothesis is rejected.

The policy takeaway from this research is that, in theory patent boxes are interesting tax rules to stimulate innovation. Yet, in practice this does not seem to be the case. Patent boxes are wildly used by MNCs to shift profits between borders.[66] Given that several studies find limited improvements in the quality of R&D, see Bradley et al. (2015), governments should consider abolishing patent boxes. Stimulating R&D via tax credits would be a better option instead (Haufler & Schindler, 2020).

To conclude, the implementation of the patent box did not bring the intended effects, as discussions in parliament have shown. Based on the results of this study, it must be concluded that the patent box did not trigger more domestic innovation and did not attract foreign R&D either. Although the most important identifying assumption holds, one should be careful interpreting the results, since these results might deviate slightly from the actual effect, as the discussion section addresses. Further research is needed to formulate more precise estimates of the effects on domestic innovation and profit shifting. In the future, when policy makers assess the functioning of the patent box, careful evaluations need to rule out whether the tax rule does more harm than good. Implementing such rules without having a clear view on its effects can

[65] See for example IBM's platform InnovationJam.

[66] Although this is not literally found in the results, the statement that the patent box is profoundly used by MNCs is all-embraced and confirmed by many studies. See for example Baumann et al. (2020), Köthenbürger et al. (2018) for European evidence or Faulkender et al. (2019) for suggestive US evidence.

have both far-reaching micro- and macroecnomic consequences. As long as neighbouring countries still hold on to it, it likely proves difficult for the government to take action and abolish the patent box.

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A Mathematical derivations

A.1 Derivations total differentials

Totally differentiating first-order condition (3.9) leads to[67]

$$dz = (1 - t_i) f_{kq} q_e^j de^j + (1 - t_i) f_{kk} dk_i^j - f_k dt_i. \tag{A.1}$$

Setting $dz = 0$ and solving for de^j gives

$$\begin{aligned} 0 &= (1 - t_i) f_{kq} q_e^j de^j + (1 - t_i) f_{kk} dk_i^j - f_k dt_i \\ -(1 - t_i) f_{kq} q_e^j de^j &= (1 - t_i) f_{kk} dk_i^j - f_k dt_i \\ de^j &= -\frac{(1 - t_i) f_{kk}}{(1 - t_i) f_{kq} q_e^j} dk_i^j + \frac{f_k}{(1 - t_i) f_{kq} q_e^j} dt_i \\ de^j &= -\frac{f_{kk}}{f_{kq} q_e^j} dk_i^j + \frac{f_k}{(1 - t_i) f_{kq} q_e^j} dt_i. \end{aligned} \tag{A.2}$$

Doing the same as above for dk_i^j makes

$$\begin{aligned} 0 &= (1 - t_i) f_{kq} q_e^j de^j + (1 - t_i) f_{kk} dk_i^j - f_k dt_i \\ -(1 - t_i) f_{kk} dk_i^j &= (1 - t_i) f_{kq} q_e^j de^j - f_k dt_i \\ dk_i^j &= -\frac{(1 - t_i) f_{kq} q_e^j}{(1 - t_i) f_{kk}} de^j + \frac{f_k}{(1 - t_i) f_{kk}} dt_i \\ dk_i^j &= -\frac{f_{kq} q_e^j}{f_{kk}} de^j + \frac{f_k}{(1 - t_i) f_{kk}} dt_i. \end{aligned} \tag{A.3}$$

Totally differentiating first-order condition (3.10) gives the following

$$dz = \left((1 - \tau_j) \sum_i (f_{qq} q_e^j + f_q q_{ee}^j) - c_{ee} \right) de^j + (1 - \tau_j) \sum_i f_{qk} q_e^j dk_i^j - \sum_i f_q q_e^e d\tau_j. \tag{A.4}$$

At last, the total derivative of equation (3.12) is given by

$$dz = dt_i - d\tau_j - \theta_{aa} da_i^j. \tag{A.5}$$

[67] The cost of capital r is seen as exogenous and therefore $dr = 0$.

A.2 Derivations comparative statics

By substituting equation (A.2) into equation (A.4) and setting $dz = 0$ gives

$$0 = \left((1-\tau_j)\sum_i \left(f_{qq}q_e^j + f_q q_{ee}^j\right) - c_{ee}\right)\left(-\frac{f_{kk}}{f_{kq}q_e^j}dk_i^j + \frac{f_k}{(1-t_i)f_{kq}q_e^j}dt_i\right) + (1-\tau_j)\sum_i f_{qk}q_e^j dk_i^j - \sum_i f_q q_e^j d\tau_j. \tag{A.6}$$

Working out the parentheses makes

$$0 = -\frac{\left((1-\tau_j)\sum_i \left(f_{qq}q_e^j + f_q q_{ee}^j\right) - c_{ee}\right) f_{kk}}{f_{kq}q_e^j}dk_i^j + \frac{\left((1-\tau_j)\sum_i \left(f_{qq}q_e^j + f_q q_{ee}^j\right) - c_{ee}\right) f_k}{(1-t_i)f_{kq}q_e^j}dt_i + (1-\tau_j)\sum_i f_{qk}q_e^j dk_i^j - \sum_i f_q q_e^j d\tau_j.$$

Dividing by $(1-\tau_j)$ and taking terms including dk_i^j to the left-hand side leads to

$$\frac{\left(\sum_i \left(f_{qq}q_e^j + f_q q_{ee}^j\right) - \frac{c_{ee}}{(1-\tau_j)}\right) f_{kk}}{f_{kq}q_e^j}dk_i^j - \sum_i f_{qk}q_e^j dk_i^j = \frac{\left(\sum_i \left(f_{qq}q_e^j + f_q q_{ee}^j\right) - \frac{c_{ee}}{(1-\tau_j)}\right) f_k}{(1-t_i)f_{kq}q_e^j}dt_i - \frac{\sum_i f_q q_e^j}{(1-\tau_j)}d\tau_j.$$

Multiplying with $f_{qk}q_e^j$ and keeping dk_i^j outside the parentheses delivers

$$\left[\left(\sum_i \left(f_{qq}q_e^j + f_q q_{ee}^j\right) - \frac{c_{ee}}{(1-\tau_j)}\right) f_{kk} - \sum_i \left(f_{qk}q_e^j\right)^2\right] dk_i^j = \frac{\left(\sum_i \left(f_{qq}q_e^j + f_q q_{ee}^j\right) - \frac{c_{ee}}{(1-\tau_j)}\right) f_k}{(1-t_i)}dt_i - \frac{\sum_i \left(f_q q_e^j\right) f_{qk}q_e^j}{(1-\tau_j)}d\tau_j. \tag{A.7}$$

By substituting equation (A.3) into equation (A.4) and setting $dz = 0$ gives

$$0 = \left((1-\tau_j)\sum_i \left(f_{qq}q_e^j + f_q q_{ee}^j\right) - c_{ee}\right) de^j + (1-\tau_j)\sum_i f_{qk}q_e^j\left(-\frac{f_{kq}q_e^j}{f_{kk}}de^j + \frac{f_k}{(1-t_i)f_{kk}}dt_i\right) - \sum_i f_q q_e^e d\tau_j. \tag{A.8}$$

Working out the parentheses makes

$$0 = \left((1-\tau_j) \sum_i \left(f_{qq} q_e^j + f_q q_{ee}^j \right) - c_{ee} \right) de^j - \frac{(1-\tau_j) \sum_i \left(f_{qk} q_e^j \right)^2}{f_{kk}} de^j$$
$$+ \frac{(1-\tau_j) \sum_i \left(f_{qk} q_e^j \right) f_k}{(1-t_i) f_{kk}} dt_i - \sum_i f_q q_e^j d\tau_j.$$

Dividing by $(1-\tau_j)$ and taking terms including de^j to the left-hand side leads to

$$\frac{\sum_i \left(f_{qk} q_e^j \right)^2}{f_{kk}} de^j - \left(\sum_i \left(f_{qq} q_e^j + f_q q_{ee}^j \right) - \frac{c_{ee}}{(1-\tau_j)} \right) de^j = \frac{\sum_i \left(f_{qk} q_e^j \right) f_k}{(1-t_i) f_{kk}} dt_i - \frac{\sum_i f_q q_e^j}{(1-\tau_j)} d\tau_j.$$

Multiplication with $-f_{kk}$, taking de^j outside of the parentheses delivers

$$\left[\left(\sum_i \left(f_{qq} q_e^j + f_q q_{ee}^j \right) - \frac{c_{ee}}{(1-\tau_j)} \right) f_{kk} - \sum_i \left(f_{qk} q_e^j \right)^2 \right] de^j = \frac{\sum_i \left(f_q q_e^j \right) f_{kk}}{(1-\tau_j)} d\tau_j - \frac{\sum_i \left(f_{qk} q_e^j \right) f_k}{(1-t_i)} dt_i. \tag{A.9}$$

Now equations (A.7) and (A.9) are rearranged such that they have a common term in front of dk_i^j and de^j.

Second-order conditions To derive the comparative statics of the theoretical framework, it needs to be determined whether we are dealing with maximum or a minimum. Therefore we can test this in a Hessian matrix.

$$H(k_i^j, e^j) = \begin{bmatrix} (1-t_i) f_{kk} & (1-t_i) f_{kq} q_e^j \\ (1-t_i) f_{kq} q_e^j & \sum_i \left(f_{qq} q_e^j + f_q q_{ee}^j \right) - \frac{c_{ee}}{(1-\tau_j)} \end{bmatrix} \tag{A.10}$$

Let $det(H)$ be the determinant of matrix $H(k_i^j, e^j)$

$$det(H(k_i^j, e^j)) = (1-t_i) f_{kk} \left(\sum_i \left(f_{qq} q_e^j + f_q q_{ee}^j \right) - \frac{c_{ee}}{(1-\tau_j)} \right) - \left((1-t_i) \sum_i f_{kq} q_e^j \right)^2 = (1-t_i) A. \tag{A.11}$$

A maximum requires $det(H) > 0$ so that the following condition must hold:

$$\left(\sum_i \left(f_{qq} q_e^j + f_q q_{ee}^j \right) - \frac{c_{ee}}{(1-\tau_j)} \right) f_{kk} > \sum_i \left(f_{kq} q_e^j \right)^2. \tag{A.12}$$

If condition (A.12) applies (or $A > 0$), then it is guaranteed that profits reach a maximum in the optimum.

Comparative statics Recall that $f_q > 0$, $f_{qq} < 0$, $f_k > 0$, $f_{kk} < 0$, $f_{kq} > 0$, $q_e^j > 0$, $q_{ee}^j < 0$, $c_e > 0$, $c_{ee} > 0$, $\theta_a > 0$, $\theta_{aa} > 0$. In addition, from the second order conditions, $A > 0$. Using the equation found in (A.9) and setting $d\tau_j = 0$ gives

$$\frac{de^j}{dt_i} = -\frac{\frac{\sum_i \left(f_{qk} q_e^j\right) f_k}{(1-t_i)}}{A} < 0. \tag{A.13}$$

Setting $dt_i = 0$ instead of $d\tau_j = 0$ delivers

$$\frac{de^j}{d\tau_j} = \frac{\frac{\sum_i \left(f_q q_e^j\right) f_{kk}}{(1-\tau_j)}}{A} < 0. \tag{A.14}$$

Moreover, using equation (A.7) and setting $d\tau_j = 0$ gives

$$\frac{dk_i^j}{dt_i} = \frac{\frac{\left(\sum_i \left(f_{qq} q_e^j + f_q q_{ee}^j\right) - \frac{c_{ee}}{(1-\tau_j)}\right) f_k}{(1-t_i)}}{A} < 0. \tag{A.15}$$

Setting $dt_i = 0$ instead of $d\tau_j = 0$ makes

$$\frac{dk_i^j}{d\tau_j} = -\frac{\frac{\sum_i \left(f_q q_e^j\right) f_{qk} q_e^j}{(1-\tau_j)}}{A} < 0. \tag{A.16}$$

Turning to the profit shifting element, using equation (A.5) and setting $d\tau_j = 0$ gives

$$\frac{da_i^j}{dt_i} = \frac{1}{\theta_{aa}} > 0. \tag{A.17}$$

Setting $dt_i = 0$ instead of $d\tau_j = 0$ leads to

$$\frac{da_i^j}{d\tau_j} = -\frac{1}{\theta_{aa}} < 0. \tag{A.18}$$

B Tables

Table B.1: List of NUTS 3 regions included

Austria	The Netherlands	Norway
Bludenz-Bregenzer Wald	Alkmaar en omgeving	Akershus
Lungau	East-South-Holland	Aust-Agder
Klagenfurt-Villach	Delft and Westland	Buskerud
Pinzgau-Pongau	North Friesland	Finnmark
Graz	Arnhem/Nijmegen	Hedmark
Mühlviertel	Greater Rijnmond	Hordaland
Nordburgenland	Hague's agglomeration	Møre og Romsdal
Oststeiermark	Leiden and Bulb's agglomeration	Nordland
Östliche Obersteiermark	Kop van Noord-Holland	Nord-Trøndelag
Innsbruck	Central North Brabant	Oppland
Außerfern	Achterhoek	Oslo
Innviertel	Central-Limburg	Østfold
Mostviertel-Eisenwurzen	Greater Amsterdam	Rogaland
Niederösterreich-Süd	Haarlem's agglomeration	Sogn og Fjordane
Oberkärnten	IJmond	Sør-Trøndelag
Linz-Wels	East Groningen	Telemark
Osttirol	North Drenthe	Troms
Mittelburgenland	Flevoland	Vest-Agder
Liezen	Delfzijl en omgeving	Vestfold
Rheintal-Bodenseegebiet	North Limburg	
Salzburg und Umgebung	North Overijssel	
Sankt Pölten	Northeast North Brabant	
Steyr-Kirchdorf	Overig Groningen	
Südburgenland	Overig Zeeland	
Traunviertel	South Limburg	
Tyrolean Oberland	Southeast Brabant	
Tyrolean Unterland	Southeast Drenthe	
Unterkärnten	Southeast Friesland	
Vienna	Southeast South Holland	
Waldviertel	Southwest Drenthe	
Weinviertel	Southwest Friesland	
West- und Südsteiermark	Southwest Gelderland	
Westliche Obersteiermark	Southwest Overijssel	
Wiener Umland/Nordteil	The Gooi and Vecht	
Wiener Umland/Südteil	Twente	
	Utrecht	
	Veluwe	
	West North Brabant	
	Zaanstreek	
	Zeeland Flanders	

Regions determined based on Eurostat. For more information, see Eurostat (2020).

Table B.2: List of sectors and technology fields

Sector number	Sector	field
1	Electrical engineering	Electrical machinery, apparatus, energy
1	Electrical engineering	Audio-visual technology
1	Electrical engineering	Telecommunications
1	Electrical engineering	Digital communication
1	Electrical engineering	Basic communications processes
1	Electrical engineering	Computer technology
1	Electrical engineering	IT methods for management
1	Electrical engineering	Semiconductors
2	Instruments	Optics
2	Instruments	Measurement
2	Instruments	Analysis of biological materials
2	Instruments	Control
2	Instruments	Medical technology
3	Chemistry	Organic fine chemistry
3	Chemistry	Biotechnology
3	Chemistry	Pharmaceuticals
3	Chemistry	Macromolecular chemistry, polymers
3	Chemistry	Food chemistry
3	Chemistry	Basic materials chemistry
3	Chemistry	Materials, metallurgy
3	Chemistry	Surface technology, coating
3	Chemistry	Micro-structural and nano-technology
3	Chemistry	Chemical engineering
3	Chemistry	Environmental technology
4	Mechanical engineering	Handling
4	Mechanical engineering	Machine tools
4	Mechanical engineering	Engines, pumps, turbines
4	Mechanical engineering	Textile and paper machines
4	Mechanical engineering	Other special machines
4	Mechanical engineering	Thermal processes and apparatus
4	Mechanical engineering	Mechanical elements
4	Mechanical engineering	Transport
5	Other fields	Furniture, games
5	Other fields	Other consumer goods
5	Other fields	Civil engineering

Source: Squicciarini et al. (2013)

Table B.3: Differences-in-differences estimation on invention contributions (2004–2009)

	Domestic invention contribution			Foreign invention contribution		
	(1)	(2)	(3)	(4)	(5)	(6)
Patent box regime	9.605***	7.620**	9.468***	6.823***	5.971*	6.620***
	(0.000)	(0.479)	(0.047)	(0.000)	(0.484)	(0.040)
Patent box active	-3.493***	-3.437***	-3.517***	-2.412***	-2.440***	-2.460**
	(0.000)	(0.038)	(0.054)	(0.000)	(0.017)	(0.057)
Corporate tax rate	-22.902***	-31.296**	-27.390*	-14.158***	-19.949*	-18.236*
	(0.000)	(0.534)	(2.248)	(0.000)	(2.989)	(2.837)
Log GDP per capita			25.187			8.740
			(14.867)			(7.484)
GDP share			-5.975			-0.786
			(3.865)			(0.630)
Population share			10.011			2.020
			(5.582)			(1.617)
Family size		1.099*	0.470		0.680	0.421
		(0.112)	(0.182)		(0.348)	(0.263)
Claims		0.407	0.010		0.097	-0.045
		(0.208)	(0.003)		(0.112)	(0.012)
Forward citations		0.751	0.376		0.418	0.250
		(0.414)	(0.533)		(0.205)	(0.394)
Constant	16.239	12.643	-261.059	8.187	7.495	-86.976
	(4.015)	(2.782)	(157.119)	(2.658)	(2.191)	(78.460)
Observations	1,875	1,875	1,875	1,875	1,875	1,875
R-squared	0.015	0.034	0.085	0.020	0.031	0.054

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. Estimations (1) to (3) are done with the domestic invention contribution as dependent variable, while estimations (4) to (6) are estimated on the foreign invention contribution. Austria is used as control group. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. Sector dummies and year dummies are included for all estimations.

Table B.4: Sectoral differences-in-differences estimation on domestic invention contribution (2004–2009)

	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields
	(1)	(2)	(3)	(4)	(5)
Patent box regime	25.903***	7.483**	11.328*	4.001	-0.136
	(0.347)	(0.342)	(0.897)	(1.193)	(0.212)
Patent box active	-13.517**	0.330	-2.320	-1.727	0.203*
	(0.942)	(0.201)	(0.431)	(0.593)	(0.020)
Corporate taks rate	-147.853*	1.106	7.339	-18.987*	-5.271
	(18.724)	(0.284)	(3.431)	(1.806)	(1.962)
Log GDP per capita	48.868	25.386	24.602	24.326*	8.749*
	(38.940)	(15.614)	(18.670)	(2.436)	(0.705)
GDP share	-15.147	-6.187	-4.205	-5.186	-2.556
	(10.013)	(4.096)	(4.660)	(2.374)	(0.494)
Population share	21.993	9.824	8.570	9.282	4.761
	(13.994)	(5.886)	(6.052)	(3.994)	(1.055)
Family size	2.102	0.501	0.145	0.266	0.224
	(1.574)	(0.311)	(0.066)	(0.177)	(0.044)
Claims	-0.078	0.082	-0.310	0.048	0.069
	(0.127)	(0.020)	(0.063)	(0.076)	(0.015)
Forward citations	-2.276	-0.693	3.307	-0.152	0.719
	(3.104)	(0.490)	(2.302)	(0.842)	(0.536)
Constant	-485.707	-277.201	-269.507	-253.799*	-93.435*
	(417.821)	(170.752)	(202.728)	(29.181)	(9.390)
Observations	300	300	300	300	300
R-squared	0.055	0.093	0.449	0.496	0.356

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. All estimations are done with the domestic invention contribution as dependent variable. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. Austria is used as control group. The year 2007 is excluded to take the lagged effects of R&D into account. Year dummies are included for all estimations. Further information on the sectors can be found in table B.2.

Table B.5: Sectoral differences-in-differences estimation on foreign invention contribution (2004–2009)

	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields
	(1)	(2)	(3)	(4)	(5)
Patent box regime	17.203***	6.632***	8.322**	1.179*	0.935**
	(0.155)	(0.066)	(0.279)	(0.101)	(0.048)
Patent box active	-9.412**	-0.957**	-1.443**	-0.384	-0.532**
	(0.345)	(0.070)	(0.080)	(0.093)	(0.033)
Corporate taks rate	-90.175	-17.664**	9.853	-9.972**	-10.334***
	(15.841)	(0.642)	(7.638)	(0.291)	(0.135)
Log GDP per capita	20.473	12.521	9.359	1.022	1.015
	(16.536)	(10.108)	(8.534)	(0.596)	(0.759)
GDP share	-2.959	-2.242	-0.785	0.787	0.692
	(1.926)	(1.392)	(1.086)	(0.249)	(0.628)
Population share	5.189	3.747	3.236	-0.461	-0.701
	(4.263)	(2.757)	(2.161)	(0.126)	(0.529)
Family size	1.684	0.442	0.266	0.205	0.140
	(1.105)	(0.186)	(0.296)	(0.044)	(0.060)
Claims	-0.081	-0.041*	-0.338	0.007	0.027
	(0.078)	(0.006)	(0.118)	(0.008)	(0.011)
Forward citations	-1.523	-0.090	2.278	0.361	0.187
	(1.304)	(0.158)	(0.842)	(0.131)	(0.186)
Constant	-194.728	-130.742	-107.770	-8.205	-7.516
	(177.681)	(110.707)	(91.040)	(6.838)	(8.321)
Observations	300	300	300	300	300
R-squared	0.046	0.059	0.320	0.469	0.304

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. All estimations are done with the foreign invention contribution as dependent variable. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. Austria is used as control group. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. The year 2007 is excluded to take the lagged effects of R&D into account.Year dummies are included for all estimations. Further information on the sectors can be found in table B.2.

Table B.6: Differences-in-differences estimation on invention contributions (2007–2015)

	Domestic invention contribution			Foreign invention contribution		
	(1)	(2)	(3)	(4)	(5)	(6)
Patent box regime	8.577***	5.769*	9.031***	4.534***	3.604*	4.503**
	(0.000)	(0.613)	(0.101)	(0.000)	(0.391)	(0.082)
Patent box active	-2.535***	-0.961	-1.484	-1.413***	-0.849	-1.086
	(0.000)	(0.289)	(0.480)	(0.000)	(0.213)	(0.175)
Corporate taks rate	-465.978***	-522.717**	-710.629	-25.822***	-43.771*	-77.216
	(0.000)	(9.634)	(147.887)	(0.000)	(5.754)	(51.854)
Log GDP per capita			25.806			5.050
			(16.812)			(5.906)
GDP share			-3.689			1.328**
			(2.914)			(0.086)
Population share			7.390			-0.568
			(3.866)			(0.553)
Family size		0.853	0.278		0.340	0.133
		(0.273)	(0.270)		(0.207)	(0.125)
Claims		0.779	0.215**		0.205	0.055**
		(0.192)	(0.009)		(0.090)	(0.002)
Forward citations		1.283	0.496		0.716	0.433
		(0.516)	(0.506)		(0.123)	(0.244)
Constant	124.588**	130.322**	-101.985	8.653*	10.462	-35.354
	(1.986)	(3.043)	(142.935)	(1.258)	(1.758)	(50.087)
Observations	3,000	3,000	3,000	3,000	3,000	3,000
R-squared	0.012	0.042	0.116	0.029	0.049	0.121

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. Estimations (1) to (3) are done with the domestic invention contribution as dependent variable, while estimations (4) to (6) are estimated on the foreign invention contribution. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. Austria is used as control group. The year 2009 is excluded to prevent from having anticipatory effects in the estimations. Coefficients on the corporate tax rate cannot be estimated in estimations (4) to (6) because of not enough variation in the values. Sector dummies and year dummies are included for all estimations.

Table B.7: Fixed effects estimation with Norway as control group (2001–2015)

	Full sample			Sample excluding 2003 and earlier		
	Patent applications	Domestic contribution	Foreign contribution	Patent applications	Domestic contribution	Foreign contribution
	(1)	(2)	(3)	(4)	(5)	(6)
Patent box active	-3.419	6.875	-10.294	6.073*	12.566	-6.494
	(9.304)	(1.156)	(8.148)	(0.575)	(5.159)	(5.734)
Corporate tax rate	23.111	88.436*	-65.325	124.528**	142.030	-17.501
	(83.595)	(10.403)	(73.192)	(3.963)	(46.184)	(50.147)
Patent box rate	22.362	-23.801	46.162	-5.135	-43.415	38.279
	(30.072)	(4.538)	(25.534)	(2.145)	(16.644)	(18.789)
Log GDP per capita	-14.251	-3.035	-11.216***	-1.517	7.115	-8.632*
	(2.370)	(2.535)	(0.165)	(1.241)	(2.377)	(1.136)
GDP share	-2.966	0.393	-3.359	0.043	2.349	-2.305
	(5.907)	(0.290)	(5.617)	(0.647)	(3.188)	(3.835)
Population share	5.924	1.498	4.426	1.066	-2.925	3.991
	(8.023)	(2.434)	(5.589)	(2.050)	(3.237)	(5.287)
Family size	0.210	0.141	0.068	0.124	0.059	0.065
	(0.102)	(0.034)	(0.068)	(0.030)	(0.032)	(0.062)
Claims	0.095*	0.077*	0.018**	0.110*	0.098	0.012
	(0.010)	(0.011)	(0.001)	(0.014)	(0.020)	(0.006)
Forward citations	-0.173	-0.109	-0.064	-0.184	-0.078	-0.107
	(0.181)	(0.133)	(0.048)	(0.139)	(0.076)	(0.063)
Constant	144.087	7.503	136.585*	-13.550	-108.549	95.000
	(41.133)	(22.843)	(18.289)	(17.538)	(38.916)	(21.379)
Observations	4,130	4,130	4,130	3,245	3,245	3,245
R-squared	0.005	0.003	0.012	0.006	0.008	0.011
Number of units	295	295	295	295	295	295

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.3) is used to estimate the different coefficients. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. Estimations (1) and (4) are done on the amount of patent applications, estimations (2) and (5) are done on the domestic invention contribution, estimations (3) and (6) have the foreign invention contribution as dependent variable. The full sample period 2001-2015 is being used in estimations (1) to (3). A reduced sample is used in estimations (4) to (6), see subsection on the common trend assumption. Norway is used as control group. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. Sector dummies and year dummies are included for all estimations.

Table B.8: Differences-in-differences estimation using a longer pre-treatment period (2001–2009)

	Patent applications	Domestic invention contribution	Foreign invention contribution
	(1)	(2)	(3)
Patent box regime	23.593	16.538	7.054
	(20.475)	(16.427)	(4.048)
Patent box active	3.860	3.526	0.334
	(1.723)	(2.244)	(0.522)
Corporate tax rate	115.406	92.124	23.282
	(18.452)	(24.978)	(6.526)
Log GDP per capita	30.633	24.849	5.784*
	(8.507)	(7.818)	(0.689)
GDP share	-1.225	-2.451	1.226*
	(4.061)	(4.214)	(0.153)
Population share	4.850	4.800	0.050
	(8.361)	(7.117)	(1.244)
Family size	1.302	0.797	0.505
	(0.892)	(0.498)	(0.394)
Claims	-0.065	0.018	-0.083
	(0.024)	(0.007)	(0.030)
Forward citations	0.349	0.156	0.193
	(0.911)	(0.551)	(0.360)
Constant	-366.873	-295.339	-71.534
	(109.459)	(92.953)	(16.506)
Observations	2,065	2,065	2,065
R-squared	0.042	0.038	0.047

Notes: ***, ** ,* indicate significance at the 1%, 5% and 10% levels. Equation (5.2) is used to estimate the different coefficients. Heteroskedastic clustered standard errors adjusted on country level are in parentheses. Norway is used as control group. The year 2006 is excluded to prevent from having anticipatory effects in the estimations. The year 2007 is excluded to take the lagged effects of R&D into account. Sector dummies and year dummies are included for all estimations.

C Graphs

Figure C.1: Patent applications per sector (2001–2006)