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TAX POLICY FOR INNOVATION

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ABSTRACT

A large number of countries around the world now provide some kind of tax incentive to encourage firms to undertake innovative activity. This paper presents the policy rationale for these incentives, discusses their design and potential effectiveness, and reviews the empirical evidence on their actual effectiveness. The focus is on the two most important and most studied incentives: R&D tax credits and super deductions, and IP boxes (reduced corporate taxes in income from patents and other intellectual property).

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Tax policy for innovation

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1 Introduction – some questions

Innovative activity on the part of firms and individuals is viewed by most economists as a key driver of productivity and economic growth. However there are good arguments that from a social welfare perspective, innovation will be undersupplied by such market agents. One of the ways in which policy makers hope to encourage innovative activity is via the treatment of such activity in corporate tax system. The two key tax policies that bear directly on innovative activity are various R&D tax credits and super deductions for R&D expense (cost reduction for an innovative input) and reduced taxes on profits from intellectual property (IP) income, commonly known as an IP box.

This article reviews what we know about these two types of tax policy, one addressed to innovation input choice, and one based on innovation output. In the process I attempt to provide answers to the following questions:

1. How does taxation affect innovation?
2. Why are there special tax incentives for innovative activity?
3. What are the consequences of different R&D design choices?
4. Do patent boxes spur innovation?
5. How does the introduction of a tax measure in one jurisdiction affect other jurisdictions?

Before doing so, however, I highlight the broader topic of which the discussion here is only a part. The impact of taxation on innovative activity goes beyond these targeted measures to encompass personal and corporate taxes imposed for other purposes. For an example, see Akcigit et al. (2018), who use US state data to show that the level of personal and corporate taxation reduces the quantity, quality, and location of innovation, both for individuals and even more strongly for firms. Innovation in their paper is measured by patents and their citations.

The present article focuses only on those tax instruments that directly target innovative activity, but it should be kept in mind that the broader tax environment may also matter. The structure of the paper is the following: The next section defines innovative activities and discusses the rationale for their support. This is followed by a detailed examination of the policy design issues and practice associated with innovation tax incentives. I then review the current use of these policies around the world in section 4 and summarize the evidence on their effectiveness in section 5. Section 6 concludes and discusses some of the broader questions that arise from the review in the earlier sections.

2 Innovation activity and the rationale for its support

At least since the work of Arrow (1962) and Nelson (1959), economists have understood that innovative activity in the form of R&D is likely to generate unpriced spillovers to other firms and to the overall economy, implying that these resources may be undersupplied due to the (relative) ease of their imitation. Arrow also noted that there may be undersupply due to the associated risk and uncertainty that cannot be diversified away or insured against. This feature of R&D investment leads to a high cost of financing, especially for new firms and small and medium-sized enterprises (SMEs).

However, R&D is only one component of innovative activity. When we look at the other components, it is less clear *a priori* that the spillovers will be as large, although this is an area about which we know relatively little empirically. The components of innovation spending by the firm are the following:

- Research – basic and applied
- Development (including experimental research and design)
- Purchase of external IP including patents, copyrights, trademarks, and technical knowhow.
- Purchase, installation, and use of technologically more advanced equipment
- Software and database activities
- Training of employees in new processes, or in supporting new products
- Marketing associated with the introduction of new or improved goods and services
- Costs of organizational innovation

The extent of potential spillovers obviously varies across the type of spending, as does appropriability via IP protection or other means. A distinction that was highlighted long ago by Nelson (1959) and recently modelled more explicitly by Akcigit et al. (2013) is that between basic and more applied research and development. The former is expected to have greater and less predictable spillovers than the latter, which would argue that is be targeted by R&D policy. It might also be argued that the returns from the purchase of new equipment as well as software and database development are largely internalized to the firm and therefore require less subsidy. However, the returns to training expense depend very much on both its specific (to the firm) nature and also on the extent to which employees are able to capture these returns in their wages in the future.

Beyond the usual market failure arguments of government policy towards private innovation expenditure, it is important to note that there is another argument in favor of government policy towards research and innovation. This argument is the fact that the production of public goods (health, environment, defense, etc.) may be greatly enhanced by research targeted towards them. This kind of research may be undersupplied for the usual reasons of lack of appropriability, and risk, but is also directed towards goods which themselves can be undersupplied because of their nonrival and/or nonexcludable nature. Economists sometimes refer to this as the double externality problem.

3 Tax policies for innovation

If we accept the rationale for the government role in encouraging innovation, what policies are commonly used to this end? There are several, some of which take the form of increasing firm incentives, and some of which involve direct spending by the government. The main difference between the two is that modifying the incentives for innovation generally leaves the direction of innovation in the hands of firms, while direct spending usually allows the government a larger role in choosing the projects that will be funded.

The incentive measures include reduced taxes depending on the level of innovation inputs or outputs of the firm as well as intellectual property rights (IPRs) such as patents on new inventions. Drawbacks to these instruments are that the firm may choose privately profitable avenues of innovation (e.g., "me-too" drugs) which do not add much to social welfare. In the case of IPRs, there is an additional cost due to the creation of some *ex post* market power that may restrict output or raise the cost of follow-on innovation.

Direct spending by government consists of subsidies for R&D or innovation, often targeted to particular type of firm or project, as well as government-performed R&D directed towards public goods (e.g., health research, defense, etc.). Targeted subsidies, especially those that choose specific projects to support tend to have high administrative costs for evaluation and auditing. Nevertheless, they are widely used around the world (Hall and Maffioli, 2008; EYGM, 2017).

In this paper I focus on the tax-related incentive measures to encourage innovation. The next few sections discuss issues in tax measure design and the two commonly used tax incentives that directly target innovative activity: R&D tax credits and super deductions, and IP boxes (reduced tax on the profits from innovation).

3.1 Some issues in design

Before describing the most commonly used tax instruments, it is useful to review the features of these instruments that are more likely to make them effective. First, is the policy instrument visible to the firm's decision-makers? That is, given limited attention and bounded rationality, does it affect their bottom line enough so that it becomes salient in decision-making?

Second, does the time horizon of benefits match that of the subsidized investment? That is, does it reduce cost or increase income in the near term, when the firm may have losses due to investment? Third and related, is the system stable enough to allow forward planning of their investment strategy by the firm?

Fourth, does it target activities with potential spillovers, such as basic research, standard setting, or spending at universities and non-profit research organizations? Also, given the evidence that SMEs face larger financial constraints, does it target their activities?

Finally, is it comparatively easy to audit? That is, do the tax authorities find it straightforward to identify expenditure or income that is qualified for the tax measure? This has proved to be difficult for many governments (Guenther, 2013) and also can discourage firms from using the measures (Appelt et al. 2017).

3.2 The practice of corporate tax in the innovation area

A number of features in the corporate tax system can be seen to subsidize innovation. The most obvious are the widely used R&D tax credit or super-deduction and the various IP boxes (reduced tax rates on income generated by intellectual property such as patents, design rights, copyright, and trademarks). Tax credits are a reduction in taxes that are based a measure of R&D spending, whereas an R&D super deduction allows for expensing of R&D at a rate higher than the 100 per cent commonly used.[1] In some cases these measures are targeted towards basic research, university cooperation, and the use of public non-profit research organizations.

But there are other instruments that favor innovative activity. The first and most important is the investment tax credit or accelerated depreciation, which reduces the cost of acquiring new equipment and information technology (IT). Surveys of innovation spending based on the Oslo Manual (OECD/Eurostat, 2018) such as those in the UK show that the most important share of innovation spending is the acquisition of new equipment, IT hardware and software related to innovation, rather than R&D spending.

Another tax feature that may favor or disfavor innovative activity is the relative treatment of debt versus equity finance. If debt is favored due to the tax deductibility of interest expense, the cost of intangible non-securable finance is relatively more expensive than investment in tangible assets (Hall, 1992).

However, the most commonly used corporate tax instrument specifically targeted towards innovation is the R&D tax credit. Given that this instrument has been used at least since the 1980s in some countries, there is considerable experience with its design. The first design

[1] The main difference between the two is that the super-deduction portion is reduced by one minus the corporate tax rate, whereas the credit does not depend on the level of the tax rate on corporate profits.

problem is that basing a credit on the total R&D spending by a firm can be expensive, given the relative smoothness of R&D spending within the firm. That is, most R&D will be done anyway and it would be desirable only to subsidize an incremental amount. The difficulty is to measure that increment – that is, what would the firm have done in the absence of the tax credit? Using the firm's own past history of spending has the negative effect of greatly reducing the nominal incentive offered by the credit due to the impact an increase today has on the increment available in the future (Appendix B.2 and Hall, 1993). So although incremental schemes can be cheaper, they have been abandoned or greatly modified by several countries (e.g., US and France).

A number of countries have introduced special provisions for collaboration with universities or non-profit research institutions, and for small or new firms, following the argument that spillovers may be larger in this case.

A tax credit or super deduction may not be useful unless there are taxes to be paid, so the better designed instruments allow for loss carry-forwards of the tax benefits, to reduce future taxes. This can be especially helpful for startups, although it still leaves them facing higher costs for their initial investments. Administratively, one way to handle this problem is that introduced by the Netherlands: reduced social charges on science and engineering employment for R&D. This is an attractive design, as the audit cost is relatively low, and it is immediately effective in reducing the firm's costs, avoiding the carry-forward problem. The downside is that it may be more complex to administer in the case of purchased external R&D. The effectiveness in this case will depend to some extent on whether the supplying firm passes through the reduced cost of their R&D to the buyer.

Recently a number of countries have introduced so-called "IP boxes," which permit considerably reduced corporate tax rates on income that is generated by a firm's intellectual property such as patents, copyrights, designs, and trademarks. Such a tax instrument is often justified as subsidy to or reward for innovative activity. However, the rationale is a bit more complex than that, as I describe in what follows.

In most developed economies, the share of company assets that is intangible has grown in recent years to the point where it is larger than tangible assets in some firms (R. E. Hall, 2001; Corrado, Hulten, and Sichel, 2009; Lev, 2018). Many of these intangibles are in fact intellectual property, covered by some form of exclusivity right. Because intangibles do not necessarily have a physical location, it is fairly easy to move them to a low tax jurisdiction, enabling lower tax obligations (Dischinger and Riedel, 2011; Mutti and Grubert, 2009). A common strategy is to pay royalties for the use of the IP to the low tax country, creating income there and cost in the source (high tax) country, reducing the total taxes to be paid (Bartelsman and Beetsma, 2003). This strategy has not escaped the attention of tax authorities and governments, and in an effort to persuade the IP assets to stay home, it is appealing to offer lower tax rates on their income. Such a tax strategy on the part of governments also reflects a view that encouraging IP asset creation and location in the country is likely to persuade firms to retain skilled jobs and R&D in the country. The conclusion is that although the encouragement of innovative activity and IP creation may be motives for lowering taxes on IP income, countries are effectively forced to do this by the presence of many low tax jurisdictions around the world into which such income could migrate.[2] It is also worth noting that three of the countries that have introduced IP boxes recently are Cyprus, Liechtenstein, and Malta, who presumably did so mainly to attract tax revenue rather than discouraging IP income from leaving.

The design of IP boxes has proved even more challenging than the design of R&D tax credits. First, what IP should be covered? All of the extant boxes include patent rights, but the other choices include trademarks, designs and models, copyrights (sometimes restricted to software), domain names, and trade secrets/knowhow (Alstadsaeter et al., 2018). Second, how is IP income to be measured and expenses to be allocated between IP and non-IP activities? Third, is acquired or existing IP to be covered or only IP newly developed in the country in question? This latter feature has now been to some extent standardized in the OECD and EU economies by the Nexus principle of the Base Erosion and Profit Shifting (BEPS) rules (OECD, 2015). Fourth, if there is also an R&D credit or super deduction available, should the tax benefit on the associated R&D be recaptured, to avoid too generous an incentive? In practice, different countries have reached different answers to these questions, so there is a wide variation around the world in patent box implementation.

3.3 Comparing R&D tax incentives and patent boxes

What is the difference between these two tax incentives and should we prefer one over the other? There are two obvious differences: first, R&D tax credits do not cover non-R&D innovation and patent boxes do not cover non-patentable innovation. Second, R&D tax incentives directly target an input to innovation that is under control of the firm, whereas patent boxes target an output, which may be affected by and indeed largely due to external causes and "luck". Obviously, in an expectational sense, the availability of lower taxes on patent income feeds back into the firm's decision-making process, but it seems rather indirect compared to a subsidy of an innovation input. In addition, tax benefits *ex post* do not really help with the immediate problem of financing the investment.

Besides the fact that they are directly related to the firm decisions on the cost and location of innovative activity, there are a number of other reasons that R&D tax credits differ from patent boxes. Patent boxes target the most appropriable part of innovation, which are the

[2] The well-known use of Ireland as an IP-related tax haven by Apple is only the tip of a very large iceberg (Ting 2014), although see Hines (2014) for a fact-based review of the evidence which suggests the problem may be less than sometimes believed.

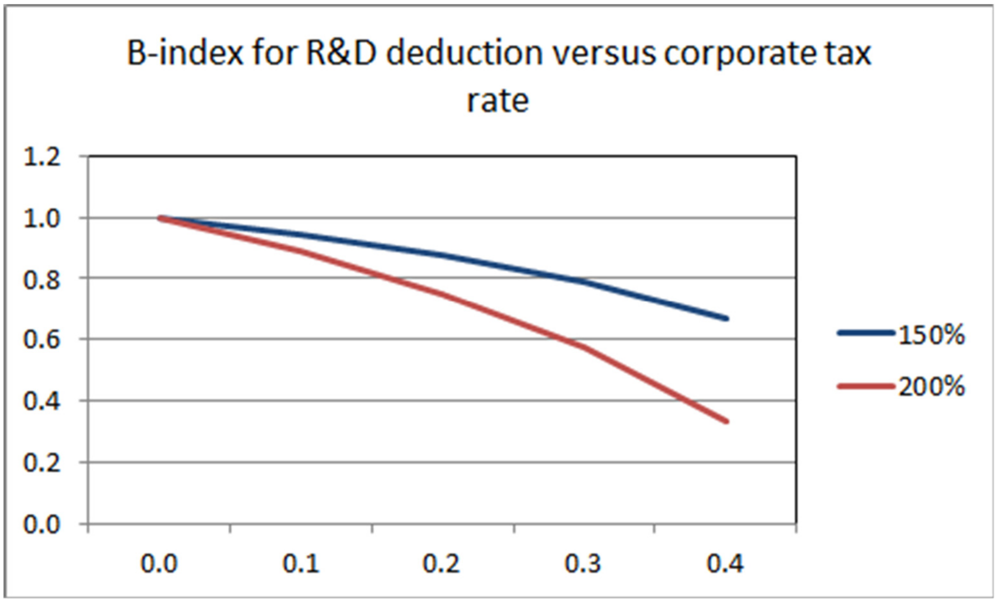
innovative activities that already receive a reward via the exclusivity of the patent. They also effectively subsidize patent assertion, some of which is "patent trolling", because all the income of firms that specialize in patent litigation and enforcement is patent income. Relatedly, they provide an additional incentive to renew patents that might otherwise be abandoned. Depending on the precise design of the patent box (gross income versus net income), they may provide an incentive to choose projects with high expenditure unrelated to R&D, since the size of the non-R&D budget will affect the amount claimed as a tax reduction.

IP boxes are also likely to face a much higher audit cost than for the R&D tax credit (which is already one of the most contentious areas of tax compliance) because the tax reduction claimed depends on the allocation of a company's income and expense between its IP and non-IP assets, something that is rife with difficulty given complementarity. This fact is probably one of the reasons that some countries have chosen to use a gross income definition for patent income.

Before leaving this review of R&D tax credits versus patent boxes, it is useful to consider the recent EU proposal for a common corporate tax base in Europe, which includes a super deduction of 150 percent, to replace patent boxes and existing R&D tax credit schemes d'Andria, Dimitrios, and Agnieszka, 2018). This may be a good idea, but it is worth pointing out that the effectiveness of this instrument depends on the corporate tax rate. Warda (2001) defined the B-index as the marginal pre-tax profit a company needs to generate to break even when spending one unit on R&D. This index is equal to one when there is no special tax treatment for R&D. Figure 1 shows the B-index as a function of the corporate tax rate (from 0 to 0.4) for two different proposed super deductions (150% and 200%).[3] The reduction in R&D cost is clearly much higher for higher corporate tax rates than for lower – something to keep in mind when setting the level of the super deduction.

[3] See the Appendix and Warda (2001) or OECD (2019) for the derivation and detailed definition of the B-Index.

Figure 1



4 The facts

In this section of the paper we briefly summarize the current use (as of 2018) around the world of the two main innovation-related tax policies: R&D tax credits and super deductions, and the patent box. For more detailed information on these instruments, see EYGM (2017), Lester and Warda (2018), and OECD (2019).

4.1 R&D tax credits

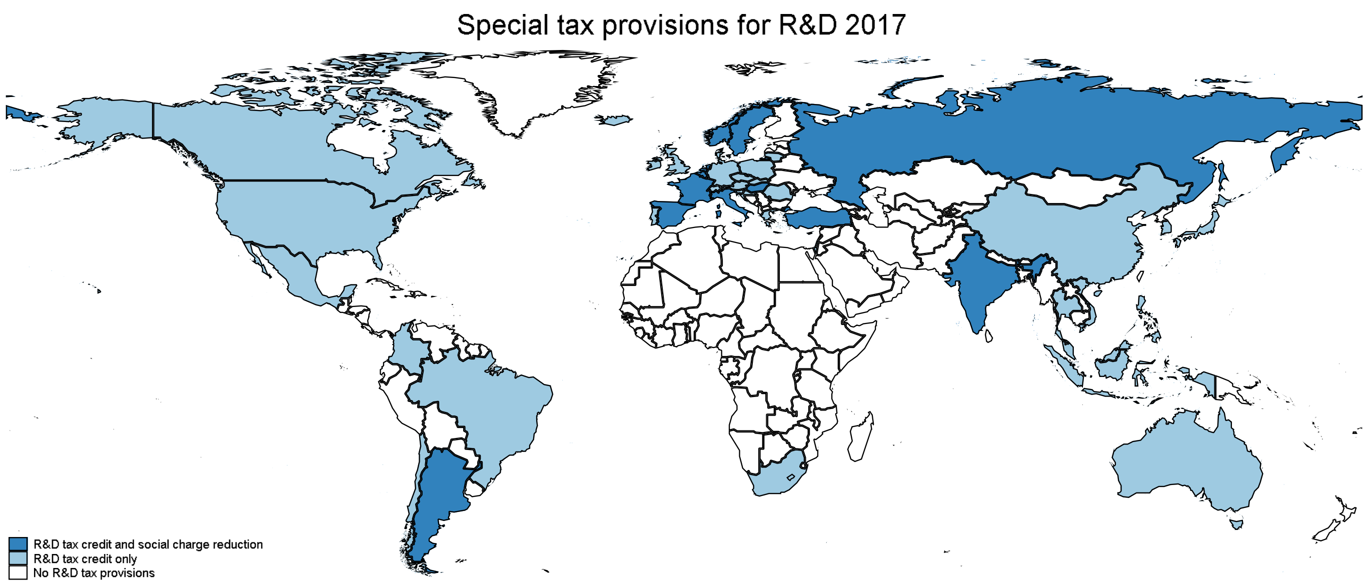
From its beginnings in the 1970s and 1980s in the US and Canada, this policy instrument is now very widely used. In 2000, 16 OECD countries provided some form of tax relief, as compared to 30 out of 35 OECD countries, along with Brazil, China, and Russia in 2017. The latest figures given in EYGM (2017) suggest that 42 countries worldwide have some kind of scheme that reduces the cost of doing R&D via the tax system. Implementation of these schemes varies widely across countries in a number of dimensions:

- Whether the scheme is a credit against taxes, or a super-deduction (>100%) of R&D expense, or even a reduction in social charges for R&D employees
- The size of the credit or deduction
- An incremental versus a level credit
- Whether or not SMEs are treated more favorably
- Details of the expense allowed
- Whether unused credits can be carried forward to be used when the firm is profitable

Comparing the tax credit policies across countries is usually done by computing the user cost of R&D capital taking into account its tax treatment (R. E. Hall and Jorgenson 1967) or by computing the B-index defined above. In general, these measures are computed for a profitable firm that increases its R&D in a single year. However, the OECD has recently developed a database of the effective subsidy rate from R&D tax incentives that is available on their website (OECD 2019), covering the years 2000 through 2018. This database provides separate estimates for profitable and loss-making firms, as well as for SMEs if they face different tax treatment. In general, loss-making firms receive a slightly smaller subsidy and SMEs a slightly larger subsidy (see also Lester and Warda, 2018).

Figure 2 shows the countries that have some form of R&D tax relief in 2017, distinguishing between those administered via the corporate profits tax and those that also include a reduction in social charges on R&D employees. In the appendix, we present figures that show the pattern of the R&D tax subsidies over time, based on the OECD (2019) data.

Figure 2: countries with R&D tax relief



4.2 IP boxes

At the time of writing, 22 countries have introduced some kind of IP box, most of them in Europe. As in the case of the R&D tax credit, these instruments vary considerably across countries. Tables comparing the various IP boxes can be found in Altstadsaeder et al. (2018) and Evers et al. (2015).

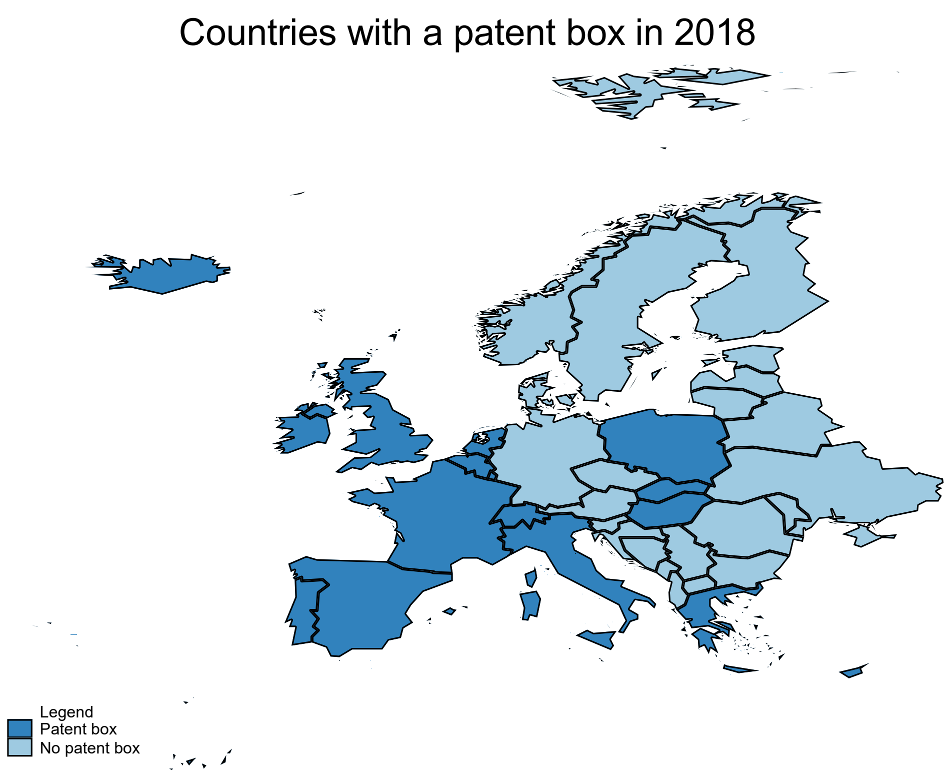
As in the case of R&D tax schemes, there is a wide variation in the rules surrounding IP boxes across countries:

- Variations in IP covered (sometimes even informal IP)

- Variations in the treatment of income and expense; reduced tax rate on gross IP income in some countries, rather than net IP income
- Recapture of past R&D expense deductions in some cases
- Rules on whether purchased or pre-existing IP is eligible, or whether further development of the income-generating product in the relevant country is necessary (modified by BEPS, as described in Section 3.2).
- Use is affected by Controlled Foreign Corporation (CFC) rules.[4]

Figure 3 shows the countries that have introduced a patent box as of 2018, many of them quite recently. Almost all are in Europe, mostly in Western Europe. The only exceptions to this are Israel, India, Japan, and Turkey (not shown on the graph). Note also that two very small European countries with relatively little innovative activity have introduced a patent box but are not visible on the graph: Liechtenstein and Malta.

Figure 3



[4] CFC rules specify that if a company in a tax haven is controlled from the home country taxes are imposed on income received in the low tax country at the domestic rate. However, the European Court of Justice has limited the application of CFC rules with the EEA area, so they do not affect patent transfers to patent box countries within the EU (Bräutigam, Spengel, and Steiff, 2017). See also Deloitte Consulting (2014).

5 Recent research on innovation tax policy evaluation

5.1 R&D tax credit evaluation

Evaluating the R&D tax credit involves at least three questions: 1) Does the credit increase business R&D as intended? 2) Do private rates of return to R&D decline, as they should, since the effect of the tax credit is to lower the cost of capital? 3) Do other firms receive increased R&D spillovers as a result of higher spending from the credit? The first has been very well studied and I summarize the results here. The second is often misinterpreted, with policy makers looking for high private returns from subsidized R&D, rather than the relatively low returns that would be expected if the cost is truly lower. The third question is the most important but also the most difficult, and there are few if any studies that look specifically at this question, although there are many studies of R&D spillovers more broadly (Hall, Mairesse, and Mohnen, 2010).

Since the early and somewhat skeptical work of Mansfield (1984, 1986), evidence on the effectiveness of R&D tax credits has accumulated to show that they are generally effective at increasing business R&D, with a price elasticity of one or higher (Hall and Van Reenen, 2000) Simulation evidence such as that reported in Hall (1993) and Mulkay and Mairesse (2012) has shown that the increase in R&D spending approximately balances or even exceeds the lost tax revenue. Recent research generally confirms the evidence surveyed in Hall and Van Reenen. For example, Chang (2018) uses US state-level data instrumented by federal tax changes to find elasticities of R&D to its tax-adjusted price of 2.8 to 3.8. Mulkay and Mairesse (2012) uses the 2008 tax changes in France to find a price elasticity of 0.4 or higher, and Dechezlepretre et al. (2016) use a regression discontinuity approach to find an elasticity of 2.6 for SMEs in the UK. See also Acconcia & Cantabene (2017) for a study of the impact of Italian R&D tax credit on financially constrained and unconstrained firms.

Two recent studies have examined spillovers from tax credit-induced R&D. The first is the previously mentioned Dechezlepretre et al. (2016). They measure the technological closeness between firms using patent data, and show that increases in R&D (due to changes in eligibility for the tax credit) in one firm increases the patenting in firms that are technologically close to that firm. Aggregating over all such firms, they find that patenting overall increases 1.7 times the direct impact on the targeted firm. Interestingly, they find no such impact (positive or negative) for firms that are close in product market space.

Balsmeier et al. (2018) base their study on the California R&D tax credit that was introduced in 1987. They find the usual increase in R&D and patenting in response to the credit. However, in contrast to Dechezlepretre et al., in their data when firms are close in technology space, competitors' market value reacts negatively to the increase. They also find that there is a general tendency for firms to pursue existing lines of research with the increased R&D rather than striking out in new directions. One major difference from the Dechezlepretre et al. study is the sample: here firms of all sizes are examined, rather than only SMEs, which may help to explain some of the differences in the findings.

There is one further impact of changes in the tax treatment of R&D that should be considered. That is the possibility that rapid changes in the tax price of R&D may have the effect of increasing its cost rather than its quantity. This is because the supply of scientists and engineers is fairly inelastic in the short run, since it takes time to produce them. In that setting one might expect the wages of existing R&D workers to increase in response to greater demand. This is what Goolsbee (1998) found for the U.S., measuring a wage elasticity of about 0.3 with respect to R&D. Using data on 15 OECD economies, Wolff and Reinthaler (2008) find an upper bound to the long run wage elasticity of 0.2, while Lokshin and Mohnen (2013) found a similar positive elasticity of about 0.2 for the Netherlands. Note that if the overall impact of the tax credit is unity, these findings suggest that the majority of the impact does go to the quantity of R&D, rather than the price.

5.2 Patent boxes

The evaluation of patent box effectiveness depends somewhat on what they are trying to achieve: 1) Prevent taxable income from migrating to low tax countries. 2) Encourage the production of knowledge and intangible assets within a country. In addition, some have questioned whether the presence of a patent box induces the transfer of patent ownership to a country without any positive benefits for the economy other than the taxation (at a low rate) of some additional corporate income.

A number of studies have been conducted on the patent box, looking at different aspects of these questions. In practice, the variation in patent box features across countries, and the limited number of countries in which they had been introduced before 2014 mean that the use of the patent box as a "natural experiment" produces somewhat imprecise and sometimes conflicting results. Accounting for all the features leaves little variation for identification of their effect. In addition, it has always been possible to transfer patent income to a low tax jurisdiction even without a patent box, so one might expect that the additional patent transfer induced by the patent box would be small (Bartelsman and Beetsma, 2003).

Gaessler, Hall, and Harhoff (2018) surveys the research that looks at the effect of introducing a patent box on patent transfer to and from a country. We then investigate the question using our own data and several features of the patent box, examining both the incentive to transfer patents to a patent box country, as well as the impact on patentable invention and R&D in the country.

Our review of the literature finds a large number of studies that have looked at the relationship between taxation and patenting, a subset of which have examined patent boxes and the location of patents. Almost none have examined other impacts of the patent box. In general, the level of corporate taxes appears to reduce the incentive to locate patents in a country, consistent with what Akcigit et al. (2018) found for U.S. state data (Karkinsky and Riedel, 2012; Boehm et al., 2015; Griffith, Miller, and O'Connell, 2014).

The evidence on patent location and ownership transfer in response to the introduction of a patent box has been studied by a number of researchers (Alstadsaeter et al., 2018; Bösenberg and Egger, 2017; Ciaramella, 2017; Bradley et al., 2015). In general, both location and transfer respond to lower tax rates on patent income, although the studies vary considerably in their approach: observation at patent, country, or firm level; the set of patents observed (pre-grant only or including post-grant); whether initial location or transfer is examined. Because of this variability, it is difficult to extract the magnitude of the impact from the various estimates. Gaessler, Hall, and Harhoff (2018) find that the transfer impact could be quite high: if the difference between the corporate tax rate and the patent income tax rate in the potential recipient country falls by 10 per cent, that leads to a four or five-fold increase in patent transfers over the next 3 years. However, like Alstadsaeter et al. and Bradley et al., we find that if there is a further development requirement for existing patents and those acquired from abroad, the impact disappears. As the nexus requirement of BEPS has eliminated the ability to simply benefit from transferring patents, we would expect the patent box impact on transfer to disappear in the future.

An interesting finding in Gaessler, Hall, and Harhoff is that patent ownership transfer is significantly discouraged by the size of the patent income tax rate in the sending company, a 15 per cent reduction in transfer if the tax rate on patent income changes by 10 percent. This result is entirely consistent with the view that patent boxes are introduced in order to keep patent ownership and related activities in the country.

Does the presence of a patent box increase patentable invention in a country? This is difficult to see in the aggregate data because all countries have an upward trend in patenting during the period. To examine this question, Gaessler, Hall, and Harhoff estimated regressions for the log of EP filings in a country-year on the patent box rate, corporate tax rate, log population, log GDP per capita, log R&D per GDP, country and year dummies, and found a small *negative* impact of the patent box on patented invention. We also found similar but insignificant results for the level of business R&D spending in the country. The only other paper to look at the impact of the patent box on R&D is that by Mohnen, Vankan, and Verspagen (2017), who find an increase in R&D person-hours in response to the patent box in the Netherlands. This may reflect the difference in the way the patent box (called an innovation box) is administered in that country, as it has covered non-patentable R&D since 2010.

Summarizing the results from these studies, I conclude first that patent boxes reduce patent ownership transfers from the country introducing them. They also induce some transfers to the country, but only if income from existing and/or acquired patents without development condition is covered. In addition, some have found that CFC rules do reduce patent ownership transfer by multinationals. More valuable patents by the usual metrics are the ones transferred, confirming the relationship of patent value metrics to the income generated by the related invention/innovation (Alstadsaeter et al, 2018; Gaessler, Hall, and Harhoff, 2018; Dudar, Spengel, and Voget, 2015). However, we can find little evidence that the introduction of a patent box increases either patentable invention or R&D investment in a country, controlling for country characteristics and overall trends.

6 Conclusion and discussion

In this article I have reviewed the main tax policies designed to encourage innovative activity and the evidence on their effectiveness. Based on this review, a number of broader policy questions suggest themselves. First, are the current tax subsidies enough? That is, do countries provide enough support for R&D and innovative activity? It is well-known that although imprecisely measured, the social returns to R&D itself are much higher than the private returns (Hall, Mairesse, and Mohnen 2010 for the micro evidence; Kao, Chiang, and Chen 1999, Keller 1998, Coe and Helpman 1995 for macro evidence).

Looking in more detail at the international spillover evidence, Branstetter (2001) and Peri (2004) find that domestic spillovers are larger than those from other countries, while Park (1995) and van Pottelsberghe (1997) find that spillovers from foreign R&D are more important for smaller open economies than for the US, Japan, and Germany. The absorptive capacity of the recipient country is also important for making use of R&D spillovers (Guellec and van Pottelsberghe 2001). All this suggests that the optimal policy may vary depending on country size, openness, and level of development. One fairly extreme view is offered by Jones and Williams (1998) using an endogenous growth model to argue that the socially optimal R&D investment in the US is at least four times the actual investment.

Although most of this literature is focused on R&D rather than innovative activity more broadly, the conclusions are that tax incentives for innovation should be even larger than they are already and also that those for larger economies are more important for global welfare. The evidence also highlights a second question: Would these policies achieve higher welfare if they were better coordinated between countries? If so, how could that be done? There are two reasons why coordination might be a good idea – the presence of cross-border spillovers and the avoidance of wasteful tax competition.

The latter has been found both for US states and across the OECD and the EU. Using eight large OECD economies 1981-1999, Bloom, Griffith, and Van Reenen (2002) find that domestic R&D responds to the foreign cost of R&D with an elasticity of about unity, roughly equal and opposite to the domestic cost response. Corrado et al. (2016) find similar results for 10 EU countries, 1995-2007. Wilson (2009) finds similar, but even larger, results for US states, where the mobility of R&D is arguably even higher. Note however that equal and opposite elasticities does not imply zero-sum effects, although it does imply that total worldwide R&D will respond more strongly to R&D tax credits in the larger economies, as suggested by Park and van Pottelsberghe. A related finding by Schwab and Todtenhaupt (2018) is that European multinationals increase their patenting and R&D activity overall when a patent box is introduced in one of the countries in which they operate.

Finally, one could argue that the introduction of the IP Box is in part an attempt to reward a broader concept of innovative activity than that which is simply R&D-related. Although this may be true, it also has the effect of rewarding successful R&D, in addition to subsidizing its cost with tax credits in many cases, and for a number of reasons discussed above it may not be the ideal solution to the question of incentivizing innovative activity more broadly. One hopes that policy makers will develop better methods in the future. Further research might also be directed to study of the non-patent use of IP boxes and their effectiveness.

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8 Appendix

8.1 The B-Index

> "The B-index is a measure of the level of pre-tax profit a "representative" company needs to generate to break even on a marginal, unitary outlay on R&D (Warda, 2001), taking into account provisions in the tax system that allow for special treatment of R&D expenditures."[5]

It is defined as follows:

$$B-index \equiv \frac{1-A}{1-\tau}$$

Where τ is the corporate tax rate and A represents the combined reduction in taxes due to R&D spending: credit, super deduction, and any increased depreciation allowances for investment in R&D equipment. If R&D is simply expensed, as it is in most countries, $A=\tau$ and the B-index is unity. See the reference in the footnote for further details and the more complex formulas used when losses can be carried forward or backwards.

8.2 Incremental tax credits

Below I explain why incremental tax credits are so difficult to design when they are based on past R&D spending by the firm. Define the following variables:

θ = tax credit rate R = R&D
π = current profit Π = Present discounted value of profits
β = discount rate

Assume that the spending eligible for the credit is the amount above the average of the last three years spending on R&D.[6] If in year t the firm increases R_t by ΔR_t, the tax credit benefit to the firm is $\Delta\pi_t = \theta\, \Delta R_t$ However, for the next 3 years, this increase is in the base R&D, so there is a cost each year given by $(\theta/3)\, \Delta R_t$. Therefore the marginal tax benefit of a one unit increase in R&D at year t is not θ, but the following:

$$\frac{\partial \Delta \Pi_t}{\partial \Delta R_t} = \theta \left[1 - \frac{(\beta + \beta^2 + \beta^3)}{3} \right]$$

The table below shows the effective tax credit as a function of the discount rate faced by the firm:

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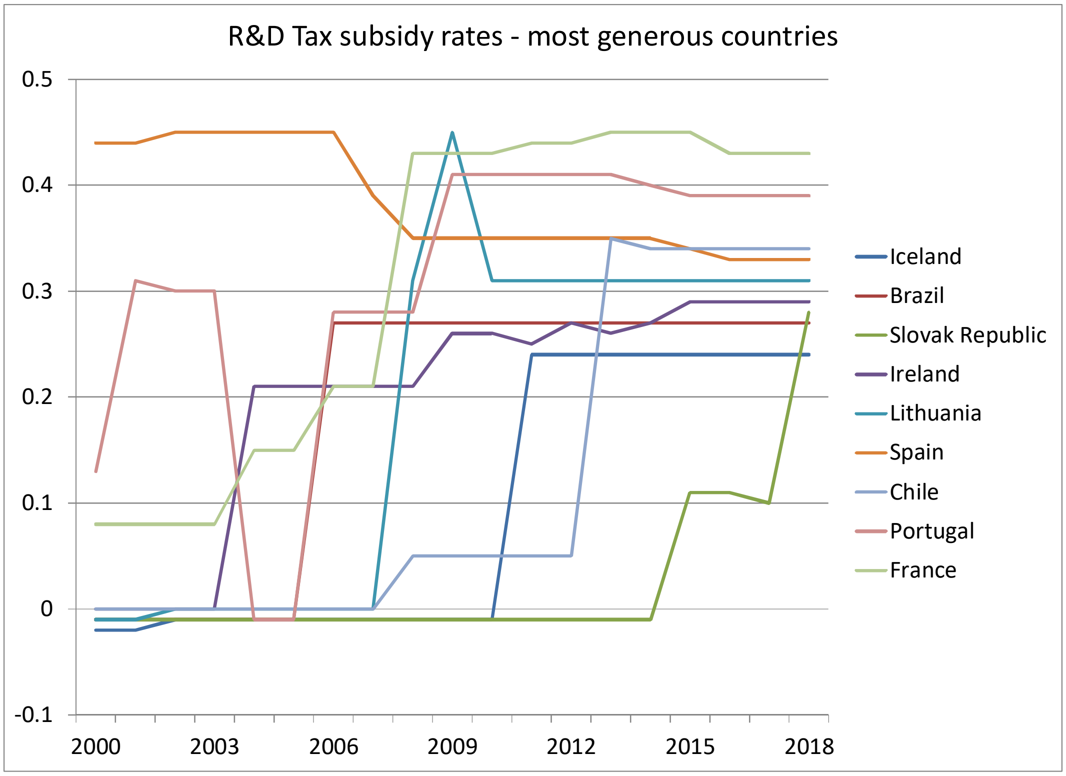
[5] From OECD(2019), https://www.oecd.org/sti/b-index.pdf

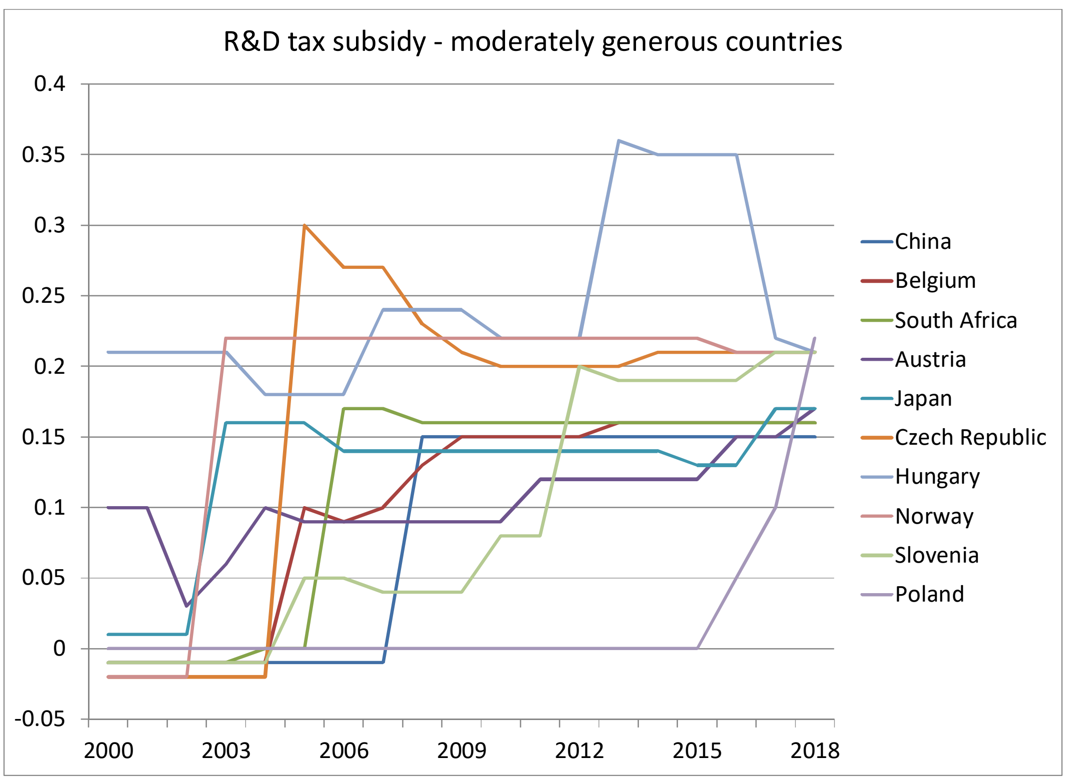
[6] This was the situation in the United States when the credit was first introduced in 1981.

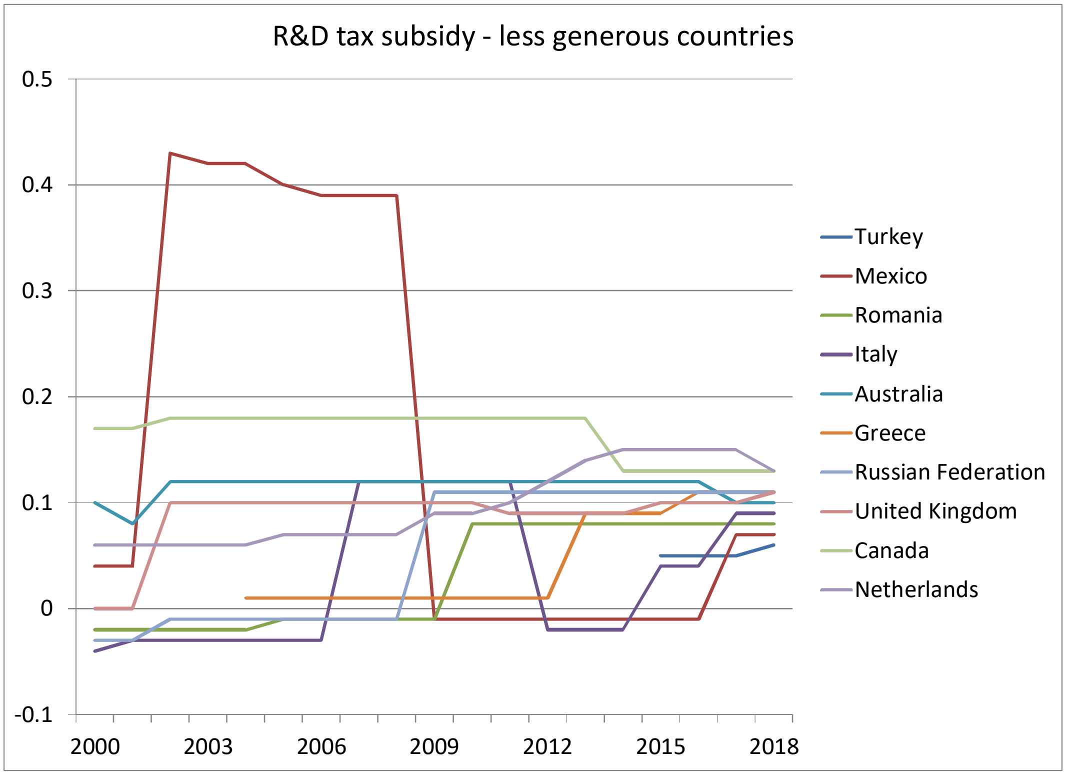
Nominal credit rate = 30%	
Discount rate	Actual credit rate
1.0	0.0
0.95	0.03 = 0.1 * 0.3
0.9	0.057 = 0.19 * 0.3

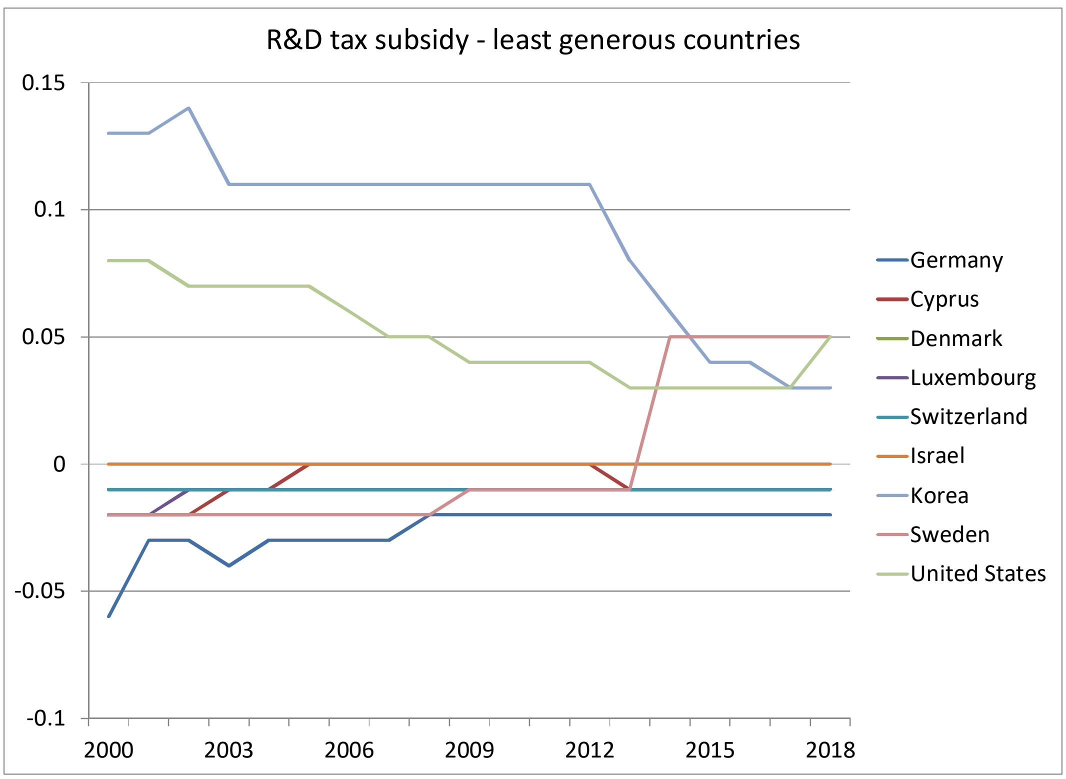
Thus the only reason there is an effective credit at all from the incremental tax credit is because the future cost of increasing R&D today is discountred.

8.3 Additional figures: R&D tax subsidy rates 2000-2018 around the world









Source: OECD (2019) database.