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5

Tax Policy for Innovation

Bronwyn H. Hall

5.1 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 the corporate tax system. The two key tax policies that bear directly on innovative activity are various tax credits and superdeductions for R&D expenses (cost reductions for an innovative input) and reduced taxes on profits from intellectual property (IP) income, commonly known as IP boxes.

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 at least partial 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?

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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 examine the relationship between patents and citation-weighted patents and the level of personal and corporate taxation at the US state level. They find that higher taxes reduce the quantity, quality, and location of innovation as proxied by patent measures, both for individuals and even more strongly for firms.

This chapter 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 and may influence the efficacy of innovation-related tax policies. The chapter is structured as follows: Section 5.2 defines innovative activities and discusses the rationale for their support. Sections 5.3 and 5.4 provide a detailed examination of the policy design issues and practices associated with innovation tax incentives, including the current use of these policies around the world. I then summarize the evidence for their effectiveness in section 5.5. Section 5.6 focuses on the use of the R&D tax credit in the United States and how it might be designed in the future. Section 5.7 concludes and discusses some of the broader questions that arise from the review in the earlier sections.

5.2 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 two additional factors that influence the supply of innovation: the associated risk and uncertainty that cannot be diversified away or insured against, and asymmetric information/moral hazard problems when the innovator and his financier are not the same. These features of R&D investment lead 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 firms include the following:

- Research (basic and applied)
- Development (including experimental research and design)
- Purchase of external IP. including patents, copyrights, trademarks, and technical know-how
- 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 modeled more explicitly by Akcigit, Hanley, and Serrano-Velarde (2013) is that between basic and applied R&D. The former is expected to have greater and less predictable spillovers than the latter, which would argue that it 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 by 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 degree to which employees are able to capture these returns in their wages in the future. The extent to which training employees raises the cost of wages because it increases the value of the employees' outside options makes the allocation of the returns from such training between private and social more complex.

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

5.3 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 allows the government a larger role in choosing the projects that will be funded.

The potential incentive measures include reduced taxes, depending on the level of innovation inputs or outputs of the firm, as well as the granting of 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 that do not add much to social welfare. A leading example is the development of "me too" drugs, slightly improved versions of existing remedies that take a large market share and therefore profits from the drugs they displace, but provide only a small benefit in terms of increases in consumer 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 a particular type of firm or project, as well as government-performed R&D directed toward the public good (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 (EYGM 2017; Hall and Maffioli 2008). As Cohen and Noll (1991) point out, one drawback of these kinds of government projects is that political support arising from the beneficiaries may make them difficult to terminate when they are unsuccessful, especially if they are large, create local employment, and require considerable investment before a path to success is seen. Nevertheless, one can also point to successful projects of this type, especially in the area of space exploration.

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

5.3.1 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 at achieving their goals. First, is the policy instrument visible to the firm's decision-makers? That is, given limited attention and bounded rationality, does it affect the company's bottom line enough so that it becomes salient in decision-making? Related to this, are there significant accounting and reporting costs required to make use of the instrument?

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

Fourth, does the instrument target activities with greater potential spillovers, such as basic research, standard setting, or spending at universities and nonprofit research organizations, rather than incremental innovation of existing products in which a firm already has a strong market position? Also, given the evidence that SMEs face larger financial constraints, does it target their activities?

Fifth, what is the appropriate level of the tax subsidy? In principle, it should be designed to lower the cost of private R&D capital to a level that induces the socially optimal level of private R&D. What we usually observe is a different quantity: the gap between the social and private rate of return to R&D. This is generally found to be quite large, but imprecisely determined (Hall, Mairesse, and Mohnen 2010; Lucking, Bloom, and Van Reenen 2019). One reason for the indeterminacy is that the social return to R&D is an unintended consequence of the individual firm's decisions. That is, the firm attempts to set its expected return to some estimate of the cost of capital, whereas no such mechanism determines the social rate of return. At the macroeconomic level, Jones and Williams (1998) use an endogenous growth model to suggest that the optimal R&D investment level for the United States may be as high as four times the current level.

The problem of determining the optimal subsidy using the estimated private and social returns to R&D is illustrated in figure 5.1, which presents a stylized version of the impact of a tax subsidy on R&D spending by the firm. The horizontal axis gives the level of R&D spending and the vertical axis its price in terms of cost of capital or rate of return. The firm's return

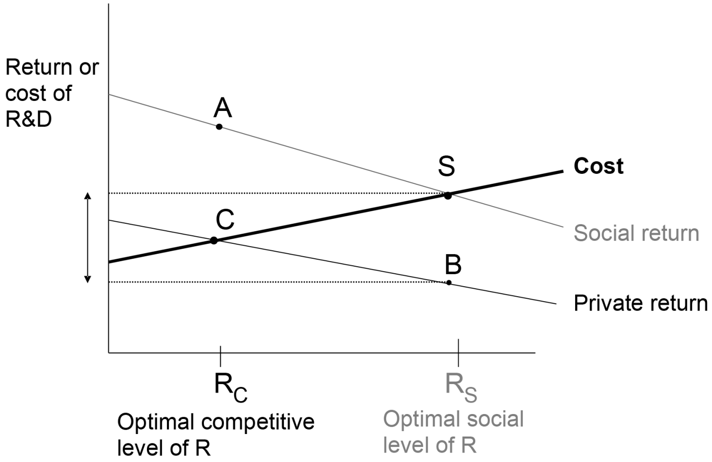

Fig. 5.1 Determining the optimal subsidy

to R&D is assumed to slope downward, as does the return to society as a whole, but society's return is higher because of spillovers. The cost of capital is assumed to increase with an increase in R&D, although this is not essential for the argument and it could be constant. What we usually observe in the various econometric studies of R&D returns is the gap between point A (the social returns to the firm's choice of R&D) and point C (the private returns to R&D at the firm, chosen to be equal to the expected cost of capital). In order to move the firm's R&D from the competitive level R_C to the socially optimal level R_S, the subsidy required is a reduction in cost from point S to point B, which is not necessarily of the same magnitude as A–C, unless the return lines are parallel.

Obviously, even this picture is oversimplified. First, there is no reason to think that the ordering of R&D projects by rate of return is the same for private and social rates. That is, the social return curve may not be a simple downward-sloping curve when plotted against R&D spending ordered by the firm's preferences. In addition, the magnitude of the spillover gap will vary by country, industry, and technology type. Attempts to take account of these factors in policy design will necessarily be fairly crude and are usually confined to attempts to distinguish basic from applied research and development.

A final design question is whether the instrument is 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 (Cowx 2020; Guenther 2013, 2015) and also can discourage firms from using the measures (Appelt et al. 2016, 2019; Guenther 2015).

5.3.2 The Practice of Corporate Tax in the Innovation Area

A number of features in the corporate tax system can be seen to subsidize innovation. As mentioned, the most obvious are the widely used R&D tax credit or superdeduction, 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 on a measure of R&D spending, whereas an R&D superdeduction allows for expensing of R&D at a rate higher than the 100 percent commonly used.[1] In some cases these measures are targeted toward basic research, university cooperation, and the use of public nonprofit research organizations.

But there are other instruments that favor innovative activity. The first

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[1] The main difference between the two is that the superdeduction 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. If the credit is recaptured, as has sometimes been the case, it will behave like a superdeduction, assuming the firm is profitable. In the case of a loss-making firm, the comparison between a credit and superdeduction will depend on the precise carryforward rules and the discount rate faced by the firm.

and most important is the investment tax credit or accelerated depreciation, which reduces the cost of acquiring new equipment and IT. Surveys of innovation spending based on the Oslo Manual (OECD/Eurostat 2018), such as those reported by Eurostat, show that in many countries the most important share of innovation spending is the acquisition of new equipment—that is, IT hardware and software related to innovation—rather than R&D spending (Eurostat 2020).

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, nonsecurable finance is relatively more expensive than investment in tangible assets (Hall 1992).

However, the most commonly used corporate tax instrument specifically targeted toward 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 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 (figure 5.A.1 and Hall 1993). So although incremental schemes can be cheaper, they have been abandoned or greatly modified over time by several countries (e.g., the United States and France).

A tax credit or superdeduction may not be useful unless there are taxes to be paid, so the better-designed instruments allow for loss carryforwards of the tax benefits, to reduce future taxes. This can be especially helpful for start-ups, 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.[2] 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 carryforward 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 the reduced cost of their R&D through to the buyer.

A second drawback to using a social charge reduction as an R&D incentive is that in some countries the accounts for social security and retirement pensions are administered quite separately from the general government

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[2] As discussed later in the chapter, the United States introduced a limited version of this instrument for small businesses in 2016.

budget. It is not always easy to make up for reducing the social charges from the general government budget for administrative reasons and would require additional legislation.

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 (Corrado, Hulten, and Sichel 2009; R. E. Hall 2001; 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 there.

The above argument implies that although the encouragement of innovative activity and IP creation may be a motive 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.[3] 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 to discourage IP income from leaving.[4]

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 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/know-how (Alstadsæter et al. 2018). From a spillover perspective, the rationale for subsidizing some of these alternative IPRs appears

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[3] 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 that suggests the problem may be less serious than is sometimes believed.

[4] These three countries combined account for fewer than 0.2 percent of European patent applications. Author's computations from European Patent Office (2019).

questionable. For example, trademarks are traditionally used for consumer protection purposes, but also to secure and maintain some degree of pricing power by preventing imitation. A similar argument applies to domain names. In the case of trade secrets or know-how, it is unclear how one could even measure the associated income.

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 Organisation for Economic Co-operation and Development (OECD) and EU economies by the nexus principle of the base erosion and profit-shifting (BEPS) rules (OECD 2015).[5] Fourth, should any tax benefits for the R&D associated with the patent 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 implementation of patent boxes (Alstadsæder et al. 2018; Gaessler, Hall, and Harhoff 2021).

5.3.3 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 innovation that is not generated via R&D, and patent boxes do not cover nonpatentable 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 (in some cases many years ex post) do not really help with the immediate problem of financing the investment.

Besides the fact that R&D tax credits are directly related to the firm's decisions on the cost and location of innovative activity, there are a number of other reasons that they differ from patent boxes. Patent boxes target the most appropriable part of innovation, which are the 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.[6] Relatedly, they provide an additional incentive to renew patents that might otherwise be abandoned, thus extending potential mar-

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[5] The nexus approach requires a link between the income benefiting from the IP regime and the extent to which the taxpayer has undertaken the underlying R&D that generated the IP asset (OECD 2015).

[6] The definition of a patent troll is controversial, but it generally means an entity that specializes in asserting patents against producers in situations where the legal costs are so high

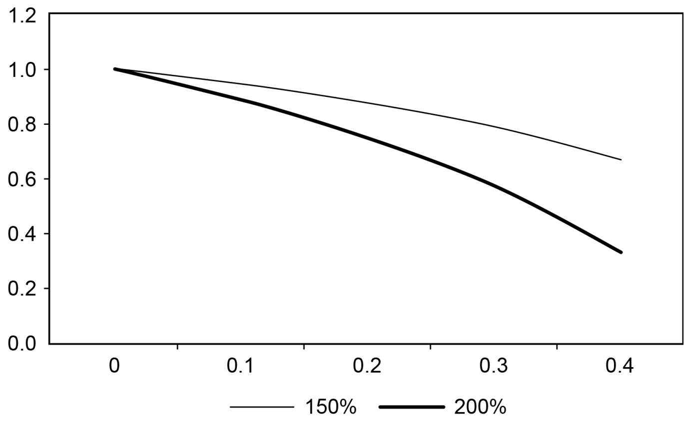

Fig. 5.2 B-index for R&D deduction versus corporate tax rate

ket power and raising search costs for inventors. 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 more likely to face much higher audit cost than the R&D tax credit, which is already one of the most contentious areas of tax compliance (Sullivan 2015; US Congress Joint Economic Committee 2016). 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 superdeduction of 150 percent, to replace patent boxes and existing R&D tax credit schemes (d'Andria, Dimitrios, and Agnieszka 2018). 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 pretax 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 5.2 shows the B-index as a function of the corporate tax rate (from 0 to 0.4) for two different proposed superdeductions (150 percent and 200 percent).[7] The reduction in R&D cost is clearly much

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that the firm will reach a financial settlement with the troll rather than defend itself, even if it believes that the patent is invalid or is not infringed.

[7] See the appendix and Warda (2001) or OECD (2019b) for the derivation and detailed definition of the B-index.

higher for higher corporate tax rates than for lower—something to keep in mind when setting the level of the superdeduction.

5.4 The Facts

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

5.4.1 R&D Tax Credits

From its beginnings in the 1970s and 1980s in the United States and Canada, this policy instrument is now very widely used. In 2000, 19 countries currently in the OECD provided some form of tax relief, as compared to 2018, when 32 out of 36 OECD countries, along with Brazil, China, and Russia, did. The latest figures given in EYGM (2017) suggest that 42 countries worldwide have some kind of tax scheme that reduces the cost of doing R&D. Implementation of these schemes varies widely across countries in a number of dimensions:

- Whether the scheme is a credit against taxes or a superdeduction (>100 percent) of R&D expense, or even a reduction in social charges for R&D employees
- The size of the credit or deduction
- Whether it is 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 its website (OECD 2019b), 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 5.3 shows the countries that offer 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

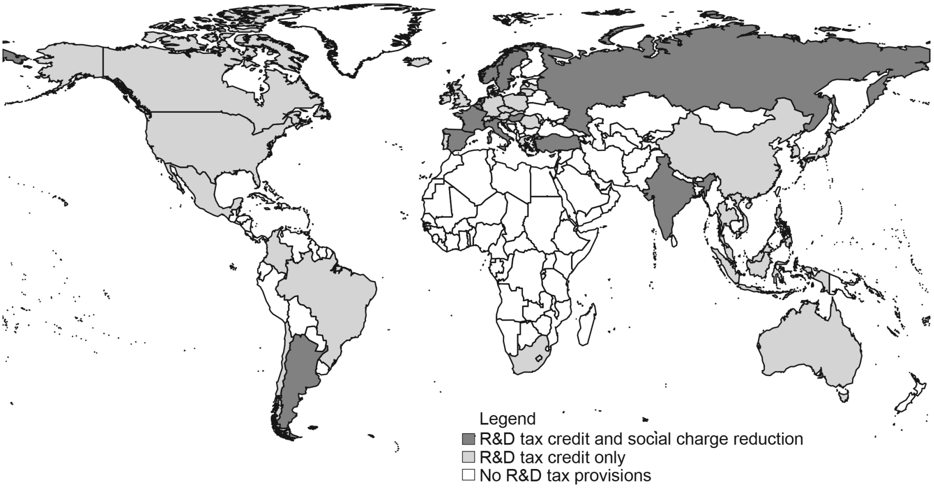

Fig. 5.3 Countries with R&D tax relief

employees. In the appendix I present figures that show the pattern of the R&D tax subsidies over time, based on the OECD (2019b) data.

5.4.2 IP Boxes

At the time of writing, 22 countries have introduced some kind of IP box, most of them in Europe. Tables comparting the various IP boxes can be found in Alstadsæder et al. (2018) and Evers, Miller, and Spengel (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 preexisting 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 5.3.2)
- Whether use is affected by controlled foreign corporation (CFC) rules[8]

Figure 5.4 shows the countries that have introduced a patent box as of 2019, many of them quite recently. Almost all are in Europe, mostly in West-

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[8] 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 within the European Economic 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).

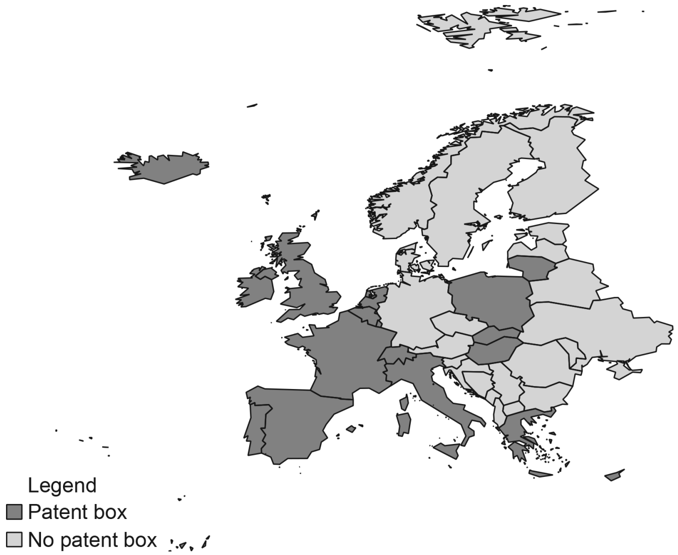

Fig. 5.4 Countries with a patent box in 2019

ern Europe. The only exceptions to this are Israel, India, Japan, and Turkey (not shown on the graph). Note also that several very small European countries with relatively little innovative activity have introduced a patent box but are not visible on the graph: Andorra, Liechtenstein, Malta, and San Marino.

5.5 Recent Research on Innovation Tax Policy Evaluation

5.5.1 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 effect of the tax credit is to lower the cost and therefore the required rate of return to R&D. 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 minus one or higher (Hall and Van Reenen, 2000). Such a result generally passes the simple cost-benefit test when compared with direct funding of R&D projects. Simulation evidence such as that reported in Hall (1993) and Mulkay and Mairesse (2013) 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 (2000). 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 (2013) use the 2008 tax changes in France to find a price elasticity of –0.4 or higher, and Dechezleprêtre et al. (2016) use a regression discontinuity approach to find an elasticity of –2.6 for SMEs in the UK. Similarly, Agrawal, Rosell, and Simcoe (2020) use a difference-in-difference analysis of a change in the eligibility of Canadian small firms for the credit to find estimated elasticities well within the range of previous work. They also show a larger effect for firms that received the tax credit as refunds due to a lack of tax liability. Guceri and Liu (2019) use similar data with an exogenous shift in eligibility thresholds to find an elasticity of –1.6. See also Acconcia and Cantabene (2017) for a study of the impact of Italian R&D tax credits on financially constrained and unconstrained firms. Blandinieres, Steinbrenner, and Weiss (2020) provide a metaregression analysis of the various estimates of the tax-adjusted price elasticity of R&D, and generally center on –1 as the consensus estimate.

One problem that is particularly important for the analyses of US data is that of obtaining the appropriate measure of research and experimentation (R&E) expenses incurred by the firm. The legislation defines the expense eligible for the credit as research and experimentation excluding routine development. However, the only publicly available data on research at the firm level is that reported in the 10-K filings at the US Securities and Exchange Commission and available to researchers via Standard and Poor's Compustat. This definition of R&D is broader than the definition eligible for the credit. Because almost all the few studies that use the actual US IRS data on R&E expense claimed do not match these data to the 10-K data at the firm level, we have only an approximate idea of the difference between the two numbers (Altshuler 1989; Cowx 2020).

Rao (2016) compares the actual R&E expense claimed and reported to the tax authorities to the R&D reported on the 10-K for a sample of about 60 firms between 1981 and 1991, finding substantial discrepancies.[9] Using

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[9] The qualified research expenditures (QREs) for the tax credit average 37 percent of 10-K-reported R&D for these firms (Rao, private communication, April 2020). However, these numbers are also confounded by another source of discrepancy: the tax credit R&D is domestic only, whereas the R&D on the 10-K is worldwide. The firms in question are largely

the actual R&E expense and controlling for endogeneity in the relationship between the tax price and R&E, she finds a tax price elasticity of –1.6, which is very similar to those found using the public R&D data. This result does raise a further question about the R&D production function, because it suggests that the disallowed portion of the R&D is complementary to the eligible R&E expense. This in turn justifies the restricted definition as lowering the cost of the tax instrument (except for the increased audit cost) while not reducing its impact.

Cowx (2020) studies the impact of R&D tax credit uncertainty on the level of R&D. She finds that a higher IRS audit risk is associated with lower levels of R&D, especially for more financially constrained firms and those with lower-quality information environments for tracking QRE expense. These effects presumably dampen the effectiveness of the credit and make the strong findings of an impact in the literature more surprising.

Two recent studies have examined spillovers from tax credit–induced R&D. The first is the previously mentioned Dechezleprêtre et al. (2016). Following on Bloom, Schankerman, and Van Reenen (2013), 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. The implication of their work is that tax-induced increases in R&D do indeed generate technological spillovers that are fairly large in magnitude.

Balsmeier et al. (2020) 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 Dechezleprêtre et al. (2016), 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 Dechezleprêtre 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: 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

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multinational enterprises (MNEs), so there will be a fair amount of R&D done outside the United States in their numbers. Thus the true fraction of domestic R&D that is QRE will be somewhat higher.

wages of existing R&D workers to increase in response to greater demand. This is what Goolsbee (1998) found for the United States, 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.

5.5.2 R&D Tax Price as an Instrument for R&D

As argued in the introduction, the primary goal of tax policy toward innovation is increases in productivity and economic growth, via subsidies to innovative activity. Evaluating the success of these policies involves first asking whether they increase innovative activity, as discussed above, and second whether the increase leads to higher productivity at the firm level, greater spillovers to other firms, and ultimately higher economic growth. In the case of R&D or other investment policies, it is tempting to use the tax price of the investment as an instrument for the investment in a productivity or growth equation. Here I consider whether this procedure is justified.

My focus is on R&D investment, but much of the discussion applies to other forms of investment policy. There are two considerations that make instrumenting R&D by its tax price problematic: (1) the usual question of whether the instrument is a valid instrument and (2) the fact that R&D is an investment. That is, the problem is inherently dynamic. If the tax price is lowered in the current year, it is expected to increase current R&D investment, and possibly future R&D investment, assuming the tax change is quasi-permanent. However, it will do nothing for the past knowledge or R&D stock, which is the relevant driver of productivity and performance. This does not invalidate the instrument, but it weakens its power. Attempting to unpack the contribution of different lags of R&D (in order to use varying tax prices as instruments) in this kind of equation has long been shown to be extremely difficult due to the high serial correlation of R&D over time within firm, sector, or country.

The validity of the tax price as an instrument using the two requirements of correlation with the R&D choice and lack of correlation with the disturbance in the productivity or growth equation depends to some extent on the level of aggregation. For firms, if the future tax price depends on the current level of R&D investment, as it has done in some countries at some times, the tax price is presumably endogenous to the current output, given the current output influence on the future R&D-output profile of the firm. This is less of a worry if the tax price is the same regardless of the firm's current and future tax positions, although in this case there will be limited variability across firms for identification. Quasi-natural experiments involving eligibility changes such as those in Dechezleprêtre et al. (2016) and Agrawal, Rosell, and Simcoe (2020) are the solution in this case.

For investigation of the relation between R&D tax policy and growth at the country level, things are much more problematic. Low productivity growth or low R&D spending is arguably a driver of the introduction and strengthening of R&D tax incentives. For the 20 countries shown in the appendix, in recent years the raw correlation between the tax price of R&D and the country's R&D intensity is not negative, as expected, but positive and equal to 0.38, lending support to this view. Controlling for the country's mean of R&D intensity over time weakens the positive correlation somewhat, but it is still significantly positive. In any case, fixed effect estimation of that kind is inappropriate if our interest is in the impact of R&D tax credits on R&D and performance. Therefore, use of tax price as an instrument for R&D in this context requires a more careful dynamic model to control for the past history of R&D and its cost.

5.5.3 Patent Boxes

The evaluation of the effectiveness of patent boxes depends somewhat on what they are trying to achieve. Does their implementation aim to prevent taxable income from migrating to low-tax countries, or to 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 until recently 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 (2021) survey 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 and the impact on patentable invention and R&D in the country. We are able to extend the analysis to 2016, by which time 17 countries had a patent box in place for at least two years.

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 US state data (Boehm et al. 2015; Griffith, Miller, and O'Connell 2014; Karkinsky and Riedel 2012).

The evidence on patent location and ownership transfer in response to the introduction of a patent box has been studied by a number of other researchers (Alstadsæter et al. 2018; Bösenberg and Egger 2017; Bradley, Dauchy, and Robinson 2015; Ciaramella 2017). 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 postgrant); whether initial location or transfer is examined. Because of this variability, it is difficult to extract the precise magnitude of the impact from the various estimates. Gaessler, Hall, and Harhoff (2021) find that the transfer impact is modest: if the difference between the corporate tax rate and the patent income tax rate in the potential recipient country falls by 10 percent, that leads to an 18 percent increase in patent transfers over the next three years, with most of the impact coming in the final year. However, like Alstadsæter et al. (2018) and Bradley, Dauchy, and Robinson (2015), 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; there is an 18 percent 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, rather than primarily to attract new patents.

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 European patent (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, and country and year dummies, and found an insignificant impact of the patent box on patented invention. We also found similar insignificant results for the level of business R&D spending in the country. If there is no requirement for further development of the transferred patents, both patented invention and business R&D in the country actually decline significantly. That is, with a further development requirement on the use of the patent to reduce taxes, there is no impact on domestic patented invention or R&D. Once that requirement is in place (as required by the nexus principle), there seems to be a disincentive for domestic innovation. We caution, however, that sample sizes are small given the limited number of countries under investigation.

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 (which is actually an innovation box) is administered in that country, as it has covered nonpatentable 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, others 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 (Alstadsæter et al. 2018; Dudar, Spengel, and Voget 2015; Gaessler, Hall, and Harhoff 2021). However, there is 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 time trends.

5.6 The R&D Tax Credit in the United States

5.6.1 History and Current Status

In the United States, the R&D tax credit (properly called the Research and Experimentation Tax Credit) has a long and varied history. It was first introduced in 1981 as an incremental credit, and it did not take long for economists to point out that the design was flawed, in that forward-looking firms would perceive an effective rate of the credit that was substantially lower than the statutory rate (table 5.A.1; Altshuler 1989; Eisner, Albert, and Sullivan 1986). In response, in 1990, the rolling base amount for the incremental credit was switched to a fixed base, determined by the 1984–1988 R&D-to-sales ratio times the current sales. This base is still in use, although it is obviously becoming more and more irrelevant as time passes.

Since its inception, R&D spending eligible for the credit has been restricted to QREs, which are typically about 65–75 percent of total R&D, although Rao (2016) uses a small sample of firms from the Statistics of Income data to report that QREs are only 37 percent of total R&D.[10] This is for two reasons:

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[10] In Rao's case the denominator of this percentage also accounts for R&D performed outside the United States, which is ineligible for the credit. This explains why her number is lower.

the desire to target expenditures that are more likely to generate spillovers, and to reduce the cost to the government of the tax credit. The definition of "qualified research" is research relying on a hard science that is intended to resolve technological uncertainty related to development of a new or improved business component, product, process, internal-use computer software, technique, formula, or invention to be sold or used in the taxpayer's trade or business. The emphasis in the definition is on the need for testing to resolve uncertainty and the use of engineering, computing, biological, or physical science. If the research passes this test, QREs are defined as follows:

- Wages paid to employees for qualified services (in practice, 69 percent of spending; US Congress, Office of Technology Assessment 1995)
- Supplies, excluding land or depreciable tangible property used in the R&D process (about 15 percent)
- 65 percent of contract research expenses paid to a third party performing qualified research, regardless of success (about 16 percent)

The main exclusions here are therefore capital spending for R&D (which is typically about 10 percent of its cost) as well as some end-stage development and social science research for marketing or other purposes. The extent to which development involves the resolution of uncertainty is the main area of auditing contention.

The US R&E tax credit has been continuously renewed, extended, and expanded at least 16 times since its introduction, with the exception of a one-year lapse between July 1995 and June 1996. As of July 1996, the credit has generally been computed based on the following formula:

$$20\% \times (\textit{Qualified Research Expenses less Base Amount}) + 20\% \times (\textit{Basic Research Payments})$$

The base amount equals the fixed-base percentage multiplied by the taxpayer's average annual gross receipts for the preceding four tax years. The base amount cannot be less than 50 percent of the taxpayer's QREs for the current tax year. The fixed-base percentage represents the ratio of the taxpayer's QREs for the base period of 1984 through 1988 to gross receipts for the same period. When introduced in 1996, the fixed-base percentage could not exceed 16 percent; currently the limit on the base amount is 50 percent of total R&D. For start-up companies (as specially defined for the credit), the fixed-base percentage is generally 3 percent, but gradually shifting to a base determined by the fifth to tenth year of the startup. All of these figures must be adjusted in the case of acquisition or disposition, and are subject to recapture by the corporate tax rate, reducing their level. They are also subject to the alternative minimum tax (AMT). Finally, basic research payments are those made to a university or nonprofit organization on a contract basis.

Effective with the PATH (Protecting Americans from Tax Hikes) Act of 2015, the R&D tax credit was made permanent rather than temporary. In addition, two exceptions to the exclusion of the R&E credit from offsetting AMT liability were made: (1) small businesses with gross receipts less than $50 million averaged over the past three years are excepted and (2) small businesses may claim up to $250,000 of R&E tax credit as a payroll tax credit against the employer share of Old-Age, Survivors, and Disability Insurance taxes. The current system contains two options for computing the credit, which differ in the definition of the base amount: (1) regular, defined as a fixed base equal to the average gross receipts over the preceding four years times the ratio of research expenses to gross receipts for the 1984–1988 period; and (2) alternative simplified credit (ASC), a fixed base defined as 50 percent of the average QRE for the three preceding tax years. The statutory credit rate for the regular credit is 20 percent, while that for the ASC is 14 percent. There is also a two-year carryback and a 20 year carryforward of the credit available for firms without taxes in the current year.

It is helpful to illustrate the complexity of the R&E tax credit computation via a few hypothetical scenarios. I present three here: (1) the regular credit, (2) the ASC, and (3) the special provisions for start-ups. All three examples avoid the complications induced by carryforwards in the case of losses and the ceilings on the amount that can be claimed. The regular credit presumes that the firm existed in a similar form during the 1984–1988 period. An example of a firm that can benefit from the regular credit is the following: Assume the total QRE-to-sales ratio in 1984–1988 is 8 percent, and the firm spends $0.9 billion out of sales of $10 billion (9 percent QRE intensity) during a subsequent year. The fixed base for the regular credit will be $0.8 billion = .08 ∗ 10 billion, and the available credit will be 0.20 ∗ (0.9–0.8) = $20 million. If we assume that QRE and sales are roughly constant for three years prior to the year of interest, the ASC for the firm will be zero, because the fixed base will be the same as the current R&D. So firms that are relatively stable but show some growth in QRE between the 1980s and the present will prefer the regular credit. Obviously, this will be a shrinking percentage of the firms as time passes, both because of firm exit and because the firm's profile in the late 1980s will become less relevant to its present spending.

The ASC computation is more likely to benefit firms whose sales are growing, but whose QRE intensity has remained the same or declined over time. It is also available to a larger number of firms, because it does not require data from the 1980s. For example, consider a firm whose sales over five years are 50, 55, 60, 65, and 70, and whose QRE intensity is 0.05 over the same period. The fixed bases in the final two years will be 2.75 and 3, implying credits of 0.14 ∗ (3.25–2.75) = 0.07 and 0.14 ∗ (3.5–3.0) = 0.07 respectively. Assuming either that the firm did not exist in 1984–1988 or that its QRE intensity was

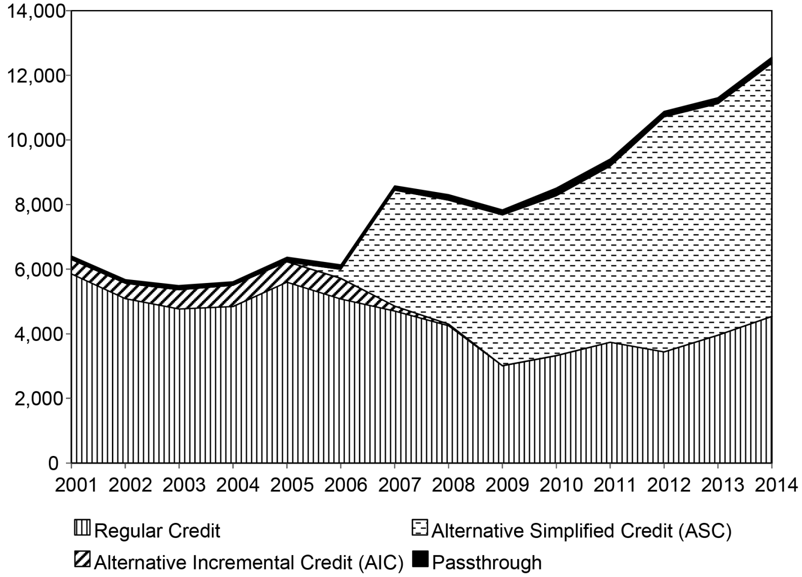

Fig. 5.5 Total R&E credit claimed on IRS Form 6765 ($millions)

Source: US Department of Treasury Statistics of Income (SOI), https://www.irs.gov/statistics/soi-tax-stats-corporation-research-credit.

higher than 0.05 during that period, in this example the firm will choose the ASC, because the regular credit would yield zero.[11]

Some start-up firm scenarios are shown in figure 5.A.3. For its first 10 years, a start-up firm will follow a relatively complex set of computations that are designed to transit the firm from a fixed-base percentage of 3 percent to one that is more reflective of the particular firm's circumstances. The result is some fairly extreme heterogeneity, depending on the particular pattern of QRE and sales growth in the firm. For a stylized R&D-intensive startup (Scenario 4) with high QRE intensity in the first three years and steady sales growth, the average credit is about 12 percent of QRE in the first six years, declining to 2 percent by year 11. The marginal credit shows a similar pattern (see the appendix for details).

Figure 5.5 shows the actual evolution of the use of the different methods of computing the R&D credit between 2001 and 2014; unfortunately the Statistics of Income (SOI) detail is not available on the website prior to 2001 or post 2014. The figure shows that the amount devoted to the credit doubled between 2006 and 2012, and that the ASC accounts for an increas-

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[11] This analysis ignores the impact of the increased QRE in the current period on the amount of credit available in the future. That impact will reduce the total value of the credit, but not to zero, so the ASC will still be preferred to the regular credit.

Table 5.1 **Statutory, effective, and average R&E credit rates by computation method for corporate taxpayers, 2013 (in percent)**

Rate	Regular method: Unconstrained by minimum base	Regular method: Constrained by 50% minimum base	Alternative Simplified Credit (ASC)
Statutory credit rate	20	20	14
Reduced credit rate (due to recapture)	13	13	9.1
Effective credit rate with no carryforward[a]	13	6.5	5
Effective credit rate with average carryforward[b]	10.7	5.3	4.1
Average credit rate[c]	5.6	6.5	5.2
Share of returns[c]	5	44	51
Share of qualified research expenses (QREs)[c]	3	28	69

Source: US Department of Treasury (2016).

[a] This assumes that firms have sufficient tax liability to use the full credit in the current year.

[b] According to OTA calculations, on average 82 percent of the current-year credit will eventually be used.

[c] According to OTA calculations using the 2013 SOI corporate sample. Returns not reporting information in appropriate fields for the calculations were dropped. This eliminated 9 percent of returns, which only accounted for 1 percent of the reported credit.

ing share of the credits claimed, as expected. The small amount claimed under the alternative incremental credit (AIC, described in the appendix) before its elimination in 2009 perhaps accounts for its discontinuation in favor of the ASC. The figure also shows the so-called pass-through amounts of the credit, which are those claimed by S corporations, partnerships, and Schedule C sole proprietorships; they are a very small percentage of the total throughout the period.

Several factors make the R&E credit rate actually experienced by the firm considerably less than the statutory rate of 20 or 14 percent. Table 5.1 presents some computations that illustrate this point; they were done by the US Office of Tax Analysis (OTA) using a sample of corporate tax returns during the 2013 year along with an assumed discount rate of 5 percent. Note first that the majority of returns and of returns weighted by QRE choose to use the ASC computation, which depends on QRE from the past three years, and therefore has a similar impact on the future credit available as the former AIC. The table analyzes three scenarios: a firm using the regular credit and unconstrained by the requirement that the base amount of QRE be 50 percent or higher;[12] a firm using the regular credit, but constrained by the 50 percent requirement; and a firm using the alternative simplified credit.

The first two lines show the relevant statutory credit rate and its value

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[12] In 2013, this requirement essentially means that the firm's R&D growth rate must be about 2.5 percentage points annually above the sales growth rate over the approximately 25-year period since the late 1980s. It is therefore no surprise that only a small share of firms are unconstrained under the regular method.

when reduced by the recapture under a corporate income tax rate of 35 percent. The next line shows the effective rate with no carryforward. This computation incorporates the impact of increasing the QRE this year on the future base; note that in the rare unconstrained case, there is no impact on the future base. This result was the original intent of the 1989 legislation. Obviously this intent has been lost as time has passed and more firms use the ASC. Line 4 corrects the effective rate for the fact that in many cases the credit will be carried forward due to insufficient tax in a given year, and in some cases will be lost due to firm exit, etc. This reduces the effective marginal credit rate even further. Finally, line 5 shows the average credit rate—that is, the credit claimed divided by the total QRE of the claimants who elected each of the three scenarios in 2013.

Note three observations about this table: First, the average credit rates (credit/QRE) are remarkably similar under the three methods. Second, the average credit rate is not that different from the marginal effective rate, except in the little-used unconstrained regular method. Third, the marginal effective credit rate is rather low, which is consistent with the OECD (2019b) figure, which shows that the US provides a lower tax subsidy to R&D than the other 30-plus OECD countries that offer a tax credit.

5.6.2 Some Thoughts on Design of the Tax Credit

Earlier it was suggested that the relevant considerations for design of tax policy toward innovation are saliency to the firm, appropriate time horizons, targeting those areas where the private-social return gap is large, and reducing auditing cost. To these might be added some consideration of the cost of the policy in relation to its benefits. In this section I consider whether there are potential improvements in the R&E tax credit toward these ends.

The current take-up of the R&E tax credit suggests that it is visible to many firms. Holtzman (2017) reports the result of a short survey of CEOs, CFOs, and tax directors at 40 companies across size and industry about the 2015 PATH Act changes. The responses were uniformly positive about its impact both on take-up and on increasing R&D, especially the impact of permanence. However, the fact that a majority of firms have switched to the ASC, which uses QRE spending in the recent past to construct a base, does suggest that the effective current credit rate (marginal or average) may be considerably lower than the 14 or 20 percent intended by the legislation. It is also true that the United States has one of the lowest effective rates among OECD economies with a research tax credit. If the goal is to encourage a substantial increase in R&D spending on the grounds that the social return is much higher than the private, it would be desirable to use a much higher credit rate along with an incremental form of the credit, to avoid the loss of inframarginal tax revenue.

With respect to targeting, in the appendix I show some detailed computations of the operation of the credit for start-up firms. These show that the start-up version of the R&E tax credit is more generous than that available to established firms, at least for firms with high R&D intensities, but that after about five years, the incentive declines considerably for the same reasons as the above. It is an open question whether the current design is anything close to optimal.

There are some remaining open questions about the design of the credit. First, does recapturing the credit for profit-making firms make sense? The effect is to provide a larger credit rate to firms with losses than to firms with profits. Second, would it be simpler for auditing purposes to define eligible R&D the same way the accounting standards define it, in order to simplify both recordkeeping and auditing? This would increase QRE by about 40 percent so that it has consequences for the cost of the credit.

5.7 Conclusion and Discussion

In this article I have reviewed the main tax policies designed to encourage innovative activity and the evidence about their effectiveness. The strongest conclusion is not new: R&D tax credits do increase R&D and roughly pay for themselves, in the sense that the increased spending meets or exceeds the lost tax revenue. Conflicting evidence exists for the proposition that the R&D thus induced spills over to other firms that are close in technological space. More research is needed on this question. There also has been little study of the specific impact of R&D induced by the credit on the return to R&D, which theory predicts should decline if the cost of R&D capital has declined. The literature on the R&D tax credit also suggests that the increased audit and compliance cost associated with more complex tax credit schemes may not be justified.

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 nonpatent use of IP boxes and 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 (for the micro evidence, see Hall, Mairesse, and Mohnen 2010; for the macro evidence, see Coe and Helpman 1995; Kao, Chiang, and Chen 1999; Keller 1998).

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 United States, 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 of 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 United States 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. (2015) 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 do not imply zero-sum effects, although they do 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. This result suggests that the global impact of an innovation incentive could be positive precisely because MNEs tend to house their innovation activity in larger countries already.

Appendix

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."[13] It is defined as follows:

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[13] From OECD (2019a).

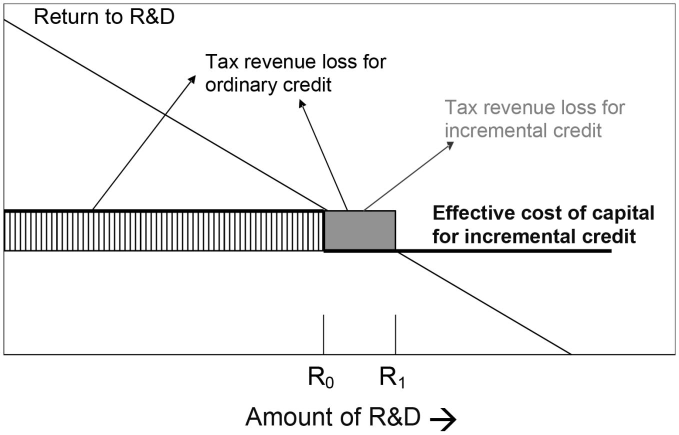

Fig. 5.A.1 Firm increasing R&D from R_0 to R_1

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

where τ is the corporate tax rate and A represents the combined reduction in taxes due to R&D spending: credit, superdeduction, 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 backward.

Incremental Tax Credits

Unlike ordinary investment, R&D spending, once established, tends to be fairly smooth from year to year within a firm (Hall 1992; Hall, Griliches, and Hausman 1986). The appeal of incremental R&D tax credits is that they target the marginal decision to increase R&D rather than subsidizing inframarginal R&D that would have been done anyway. The drawback is that every firm is different, and the best way to figure out a firm's presubsidy R&D level is to look at its past history. Thus, incremental credits tend to be based on the firm's own R&D history, which implies that a firm can directly affect its future credit availability.

Figure 5.A.1 illustrates the tax cost savings from using an incremental credit to subsidize a firm with an established ongoing R&D budget. The figure assumes that the tax authority is able to identify precisely the point R_0 at which the cost of capital needs to be lowered in order to induce the firm to increase its R&D to R_1. The tax revenue loss in the case of an incremental credit is shown in the gray rectangle (the difference in the cost of R&D capital times the amount of increased R&D). To achieve the same increase

Table 5.A.1 Effective credit rate as a function of the discount rate

Discount rate	Effective marginal credit rate	
Nominal credit rate	US in 1981 at 30%	ASC at 14%
1.0	0.0	0.0
0.95	0.030 = 0.3 * 0.10	0.077 = 0.14 * 0.55
0.9	0.057 = 0.3 * 0.19	0.083 = 0.14 * 0.59

in R&D using a level or volume credit would cost both the gray rectangle and the rectangle with vertical lines, a much higher cost for the same impact.

As was first pointed out by Eisner, Albert, and Sullivan (1986) and Altshuler (1989), the downside of the incremental credit is that it is weakened by the fact that an increase in R&D today causes a decrease in credit availability in the future.

The following argument explains 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 of spending on R&D.[14] 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 three 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:

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

Table 5.A.1 shows the effective tax credit as a function of the discount rate faced by the firm, based on the above formula, for two different statutory credit rates, 20 and 14 percent. The first two columns show the effective credit rate according to the rules as they existed in 1981–1986 for constrained and unconstrained firms, while the third second column shows the effective marginal rate under the current ASC.

The only reason there is an effective credit at all from these versions of the incremental tax credit is because the future cost to the base R&D of increasing R&D today is discounted.

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[14] This was the situation in the United States when the credit was first introduced in 1981. The current ASC uses 50 percent of the average of the last three years of spending.

Tax Treatment of Start-Ups in the United States

The PATH legislation of 2015 contains the following provisions for computing the fixed-base QRE against which the increment eligible for the tax credit can be computed. This computation applies to companies that incorporated after December 31, 1983, or had fewer than three years with QREs and revenue between January 1, 1984, and December 31, 1988. The fixed-base percentage is calculated according to the code as follows:

- §41(c)(3)(B)(ii)(I) 3 percent for each of the taxpayer's first five taxable years beginning after December 31, 1993, for which the taxpayer has qualified research expenses
- §41(c)(3)(B)(ii)(II) in the case of the taxpayer's sixth such taxable year, 1/6 of the percentage which the aggregate qualified research expenses of the taxpayer for the fourth and fifth such taxable years is of the aggregate gross receipts of the taxpayer for such years
- §41(c)(3)(B)(ii)(III) in the case of the taxpayer's seventh such taxable year, 1/3 of the percentage which the aggregate qualified research expenses of the taxpayer for the fifth and sixth such taxable years is of the aggregate gross receipts of the taxpayer for such years
- §41(c)(3)(B)(ii)(IV) in the case of the taxpayer's eighth such taxable year, 1/2 of the percentage which the aggregate qualified research expenses of the taxpayer for the fifth, sixth, and seventh such taxable years is of the aggregate gross receipts of the taxpayer for such years
- §41(c)(3)(B)(ii)(V) in the case of the taxpayer's ninth such taxable year, 2/3 of the percentage which the aggregate qualified research expenses of the taxpayer for the fifth, sixth, seventh, and eighth such taxable years is of the aggregate gross receipts of the taxpayer for such years
- §41(c)(3)(B)(ii)(VI) in the case of the taxpayer's tenth such taxable year, 5/6 of the percentage which the aggregate qualified research expenses of the taxpayer for the fifth, sixth, seventh, eighth, and ninth such taxable years is of the aggregate gross receipts of the taxpayer for such years
- §41(c)(3)(B)(ii)(VII) for taxable years thereafter, the percentage which the aggregate qualified research expenses for any five taxable years selected by the taxpayer from among the fifth through the tenth such taxable years is of the aggregate gross receipts of the taxpayer for such selected years

For purposes of the calculation, the resulting fixed-base percentage is multiplied by the average of the taxpayer's gross revenue for the four years prior to the calculation year.[15] The fixed-base percentage should only change for purposes of meeting the consistency rule or adjusting for an acquisition or disposition.

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[15] It seems clear, although not specifically mentioned, that if fewer than four years are available prior to the calculation year, the average over the years available should be used.

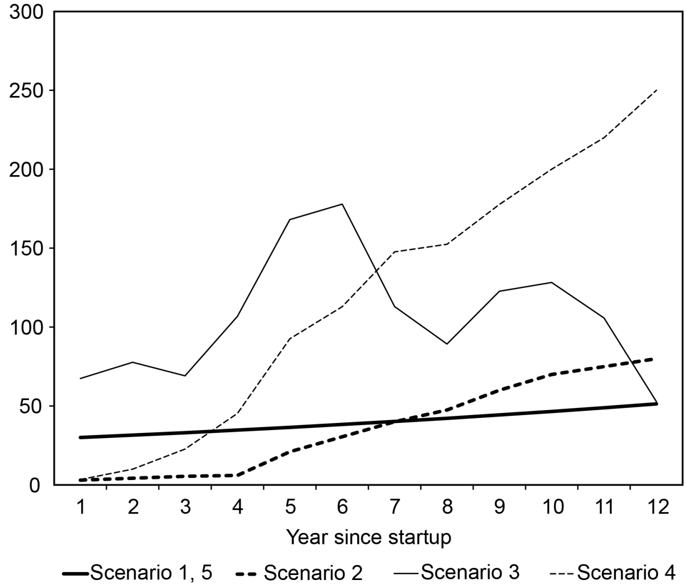

Fig. 5.A.2 Sales trend scenarios for start-up firms

Figures 5.A.2–5.A.4 show the implication of this form of computation for startups with varying patterns of R&E spending and sales growth. There are five scenarios:

1. Steady, slow sales growth with R&E to sales of 3 percent every year
2. Very low sales for four years, followed by fairly rapid increase, with the R&E intensity falling over the same period as sales are established
3. A pattern taken from a random high-tech startup on Compustat with uneven but growing sales and rapidly growing R&E intensity
4. High initial R&E spending accompanied by rapid sales growth that eventually stabilizes the R&E intensity at the relatively high level of 15 percent
5. Same as 1, but with the R&E-to-sales ratio at a constant 5 percent

If I have interpreted the computation rules correctly, the results are a bit strange. Prior to year six, the average credit share seems more or less directly related to whether the firm has an R&E intensity above 3 percent. However the differences between firms that begin with 15 percent, or 30 percent R&E intensity, do not seem that great. At year six, however, the impact of the 1/6 rule is to give all the synthetic firms an average credit that is close to the statutory 14 percent rate, since their past histories are downweighted greatly. Following year six, the average credit share declines similarly for all the scenarios, whether growing or not, with the exception of the scenario with fluctuating sales, as one would expect. Average is of course not marginal,

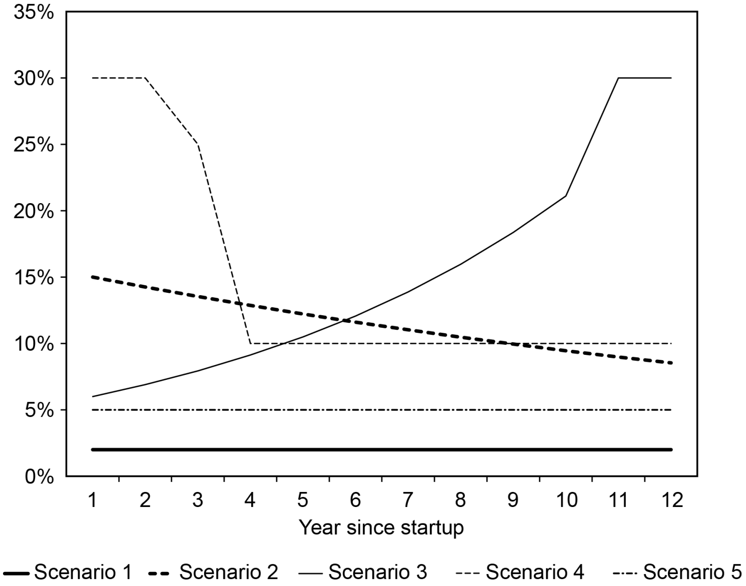

Fig. 5.A.3 QRE to sales for start-up firms

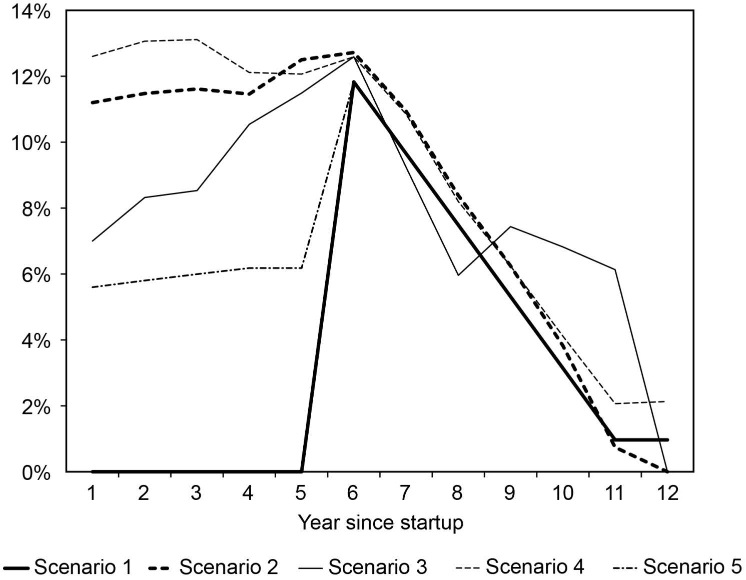

Fig. 5.A.4 Amount of tax credit as share of QRE for start-up firms

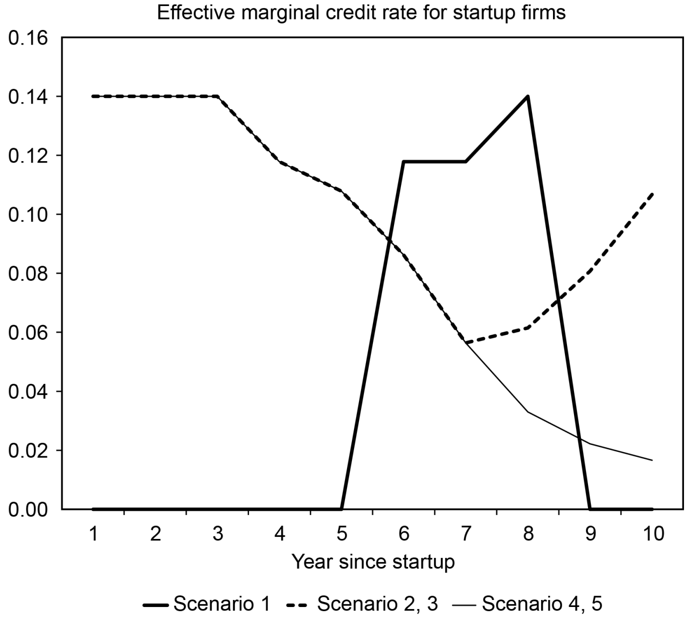

Fig. 5.A.5 **Effective marginal credit rate for start-up firms**

but it may be what is salient for the firm, as it is visible on their tax return. It is also what will be computed when a firm does pro forma forecasting to assess the appropriate R&D profile for which to plan.

Marginal rates that take into account the impact of current increases on the future fixed base are also rather heterogeneous, as shown in figure 5.A.5.[16] For Scenario 1, there is no eligibility in the first four years because the QRE intensity is quite low. Scenarios 4 and 5 are eligible throughout, and so their effective marginal credit declines to nearly zero at the end of the period when current increases affect future eligibility for four years. Scenarios 2 and 3 are not eligible at the end of the period because their QRE intensity has stopped growing, and this is reflected in marginal rates that increase again (because assuming that they remain below the base in future periods means it is not costly to increase QRE now).

Additional Figures: R&D Tax Subsidy Rates 2000–2018 around the World

Figures 5.A.6 and 5.A.7 show the R&D tax subsidy rates (1-B index) for large profit-making firms that offer some kind of R&D tax credit or superdeduction.

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[16] In computing these marginal rates I have used a discount rate of 0.95, which has been used in much of the earlier work by OTA and others. I have also used perfect foresight to forecast future QRE.

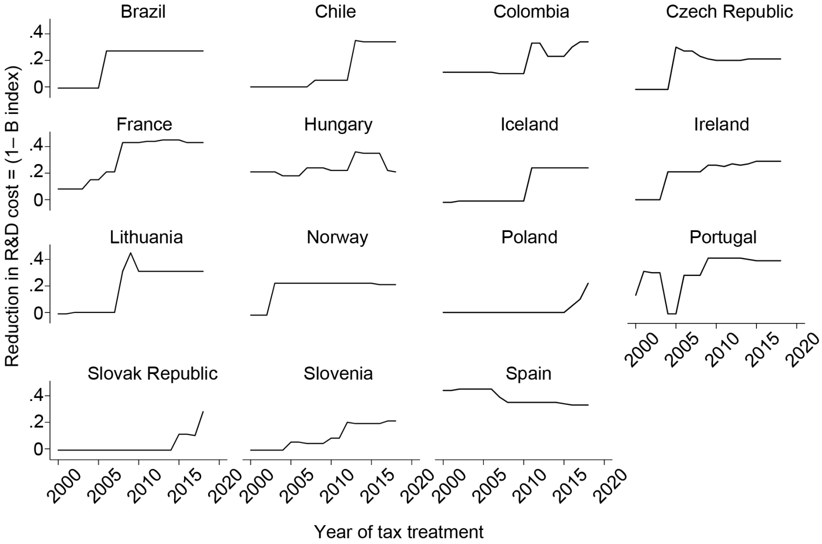

Fig. 5.A.6 Tax subsidy rate trend for the more generous countries
Source: OECD (2019c).

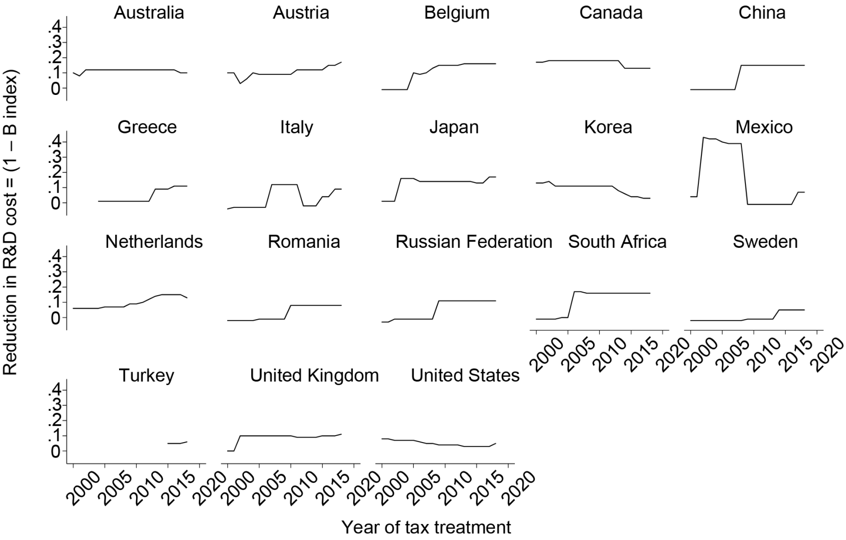

Fig. 5.A.7 Tax subsidy rate trend for the less generous countries
Source: OECD (2019c).

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