The Effectiveness of Tax Credits as a Policy Tool to Promote R & D Activity:

A Systematic Review and Meta-Regression Analysis

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Attestation of Authorship

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgement), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning."

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Abstract

Endogenous technical progress is a hall mark of endogenous growth theory which aims to provide an endogenous explanation of technological progress and economic growth within a general equilibrium framework. A principal claim to originality is that endogenous growth theory can accommodate increasing returns, and knowledge is accorded a central role in the explanation of modern technical progress and growth dynamics. To stimulate research and development (R & D) activity, governments have promoted a range of policies but principally through tax credits. However, promoting R & D activity through tax incentives is not well supported in the economics literature. Moreover, empirical studies evaluating the relationship between R & D activity and tax credits have provided mixed results which motivate this study.

Meta-regression analysis (MRA) is a form of meta-analysis and used to investigate whether study characteristics may explain heterogeneity of results among studies in a systematic review. Although researchers in psychology, education, and the health sciences have used MRA extensively, it has been little used by economists. This study performs MRA to investigate the relationship between tax credits and R & D activity; drawing data from 21 papers yielding 124 estimated effects. Information collected on each estimate allows us to test my main hypotheses; that a tax credit will lead to higher levels of R & D than without the credit, and further find out which specific policy differences have the most important impacts on estimated tax credit effects.

The results of the MRA generally confirm the effect of tax credits on R & D activity among positive and negative measures of tax credits as the analysis only considers data characteristics as moderator variables. However, the interesting finding is that the estimated impact of tax credits on R & D activity is statistically negative under all measures and types of tax credit. In addition, there is evidence that inflation and macroeconomic shocks have a relatively strong influence over the effectiveness of R & D tax credits. These findings represent a challenge for those who believe that tax credits

have stimulated R & D activity. Thus, this analysis suggests that the research design and data choices are crucial for any accurate analysis of the impact of R & D tax credits on R & D activity.

1. Introduction

Economic growth is considered extremely significant by most economists because it generates noticeable improvements in people's standards of living. The sustainability of economic growth has been a major concern of the classical economists, ranging from Smith in the late 1700s to Ricardo, John Stuart Mill, Malthus and Marx in the first half of the 1800s (Morris & King, 1967, pp. 31-63).[1] Different models for analysing the rate and cause of growth are conceived in various economic traditions. Therefore this section briefly investigates these developments from classical to endogenous growth theory, including Keynesian theory.

The classical economists, who developed the first systematic theory of growth in an agrarian economy, concentrate on the supply factors of land, labour, capital, and technological progress. Because of the steady rise in growth of population on a limited area of land, there was a steady decline of the rate of growth, i.e. diminishing returns (Meier & Baldwin, 1957, pp. 19-45; Morris & King, 1967, pp. 38-42; Sundrum, 1991, pp. 53-60). Hence classical growth theory focused mainly on the growth of these factors of production.

The field of macroeconomics was developed during the Great Depression of the 1930s primarily through the work of Keynes (1936). The crucial demand factors of gross domestic product (GDP) consist of consumption, investment, government spending, and net exports in the real macro-economy. Keynesian theory conceives investment as the source of growth and no relationship between saving and investment

[1] Adam Smith (1776, pp. 3-12) referred to the concept of division of labour in the process of economic growth (Morris & King, 1967, pp. 36-38). Division of labour enables an economy to increase the productivity of labour which is now commonly called 'learning by doing' (Meier & Baldwin, 1957, pp. 20-25). The innovative activities of producers, and workers were critical to reduce costs and improve human welfare under competitive condition.
Malthus (1798) hypothesised that output is a function of labour and land. Malthus considered population as a driver that would limit economic growth by leading to a reduction in capital accumulation. For instance, as additional workers are employed, each additional worker has less and less land to work on. Then output increases by smaller and smaller amounts, so the Malthusian model of growth is diminishing returns (Morris & King, 1967, pp. 39-40).
Marx presented that capital accumulation and technological change assume a particular form that causes capital to rise over time (Howard & King, 1988, pp. 194-207; Morris & King, 1967, pp. 43-45).

necessarily exists (Keynes, 1936, pp. 61-65, 74-85). After Keynes had analysed the short-run relationship between savings, investment, and employment, the neo-Keynesian theory extended the analysis to the long-run or dynamic relationships. For example, Harrod (1939, pp. 14-33) and Domar (1946, pp. 137-147; 1947, pp. 34-55; 1948, pp. 777-794) emphasised that capital and labour are used in a fixed proportion to each other to determine the short-run economic growth under condition of no technical progress.

Since the 1950s, the analysis of economic growth refers mainly to an industrial economy. In order to explain the empirical fact that many countries have seen steady growth in average income since 1820, neoclassical model developed by Solow (1957, pp. 312-320; 1971, pp. 101-108) not only emphasised the growth of factors, but also considered the impact of technology on the standard of living.[2][3] In the aggregate production function, aggregate output *Y* is a function of the quantities of various factors, namely land, labour, capital and technological progress. Solow (1956, pp. 65-94) treats technological progress as an exogenous public good, which is non-rival and non-excludable.[4] Research and development (R & D) is simply an alternative form of capital investment and it is the form of new goods, new markets, or new process. Under an endogenous rate of capital accumulation as well as exogenous rates of saving and

[2] The relationship between the rate of growth of the labour force and technical progress on the one hand, and the natural rate of growth on the other, can be understood by examining the definition of the *level* of labour productivity. $Q=Y/N$, where Q denotes labour productivity, Y is the level of real output and N is the level of employment. Rearranging, we have $Y=Q*N$. Suppose that Q is completely determined by the current state of technology, and that $N=L$, where L denotes the available labour force. Then we can write $Yp=Q*L$, where Yp denotes the potential level of real output. Taking logs and differentiating with respect to time on both sides of this expression, we arrive at $yp=q+l$. The potential rate of growth of output is determined by the rate of growth of the labour force and technical progress (Chaudhuri, 1989, pp. 1-77, 100-127).

[3] Then Arrow, Chenery, Minhas, and Solow (1961, pp. 225-250) introduce the two factor (capital and labour) constant elasticity of substitution (CES) production function which consists of some production functions and utility functions. The CES production function displays constant elasticity of substitution, so the production technology has a constant percentage change in factor (capital and labour) proportions. That is, a percentage change in marginal rate of technical substitution leads to a constant percentage change in labour or capital factor, and even the output.

[4] The public goods are goods and services that are both non-rival and non-excludable. In this sense, the technology is a non-rival good, namely, a good that can be used by more than one person or firm at a time. Furthermore, the non-excludable technology means that it is nearly impossible to prevent others from using it. In this case, there is no compensation to receive technology, so an individual firm is assumed to be free to exploit the technology (J. I. Bernstein & Nadiri, 1991, pp. 1-44).

population growth, a permanent increase in a rate of labour-enhancing technological progress, such as that induced by R & D, can offset the dampening effect of diminishing returns and lead to higher continuous economic growth.

Nonetheless, neoclassical economists suppose that technology variable is considered as a driving factor of economic growth outside of the model.[5] Furthermore, the simple capital-based approach omits some considerations about distortions with research, so there is little information about the true social rate of return to R & D.[6] For example, Mankiw, Romer and Weil (1992, pp. 407-438) carried out the statistical tests of the Solow model. The low R-squared values of regression based on the Solow model show that economic growth is also related to other determinants which are not included in that model.

In order to make the model more general and more realistic, endogenous growth theory (EGT) or new growth theory (NGT) indicates that technological progress is endogenously determined inside the model. The role of R & D, human capital accumulation and externalities are significant in the long-run economic growth with constant and increasing returns to capital in the 1980s. Additionally, just like classical and neoclassical theory, saving is assumed to wholly transform into investment in endogenous growth theory. Hence, EGT assumes non-diminishing marginal returns to accumulated factors of production and economic growth is determined by saving itself.

The remainder of the paper is organised as follows. Section 2 describes the relationship between R & D and economic growth from various theoretical perspectives,

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[5] The Solow model treats saving, population growth, and technological progress as exogenous, determined outside the model. That is, the model does not explain why these variables are what they are or how economic policy might be able to influence them. But the model has pointed the direction where the determinant of long-run economic growth (Solow, 1956, pp. 65-94).

[6] The non-rivalrous but excludable character of R & D capital increase the rate of knowledge diffusion, so there is existing spillovers of R & D. Spillovers decrease product price and production cost, so output (or product market size) would increase. Based on spillovers, rates of return can differ among physical and R & D capital. For physical capital, there are no externalities, so its social rate of return is equal to its private rate. But R & D spillovers, which define externalities, affect product price and production cost, and then social rates of return to R & D is different from private returns (J. Bernstein & Nadiri, 1988, pp. 429-434).

as well as introducing the key variables used in the growth model. The impact of tax incentives on R & D activity is then examined before Section 3 briefly introduces meta-analysis, explains how the studies have been selected, and provides an overview of relevant study characteristics. Section 4 then presents the empirical results from applying the meta-regression analysis (MRA); establishes the associations between study characteristics and study outcomes. At the end, Section 5 summarises the findings of the analysis and discusses the implications of these for empirical research on R & D.

2. Literature Review

2.1 Theoretical perspectives

Regarding the technical conditions of production, the EGT assumes non-diminishing marginal returns to accumulated factors (which include not only physical capital but also human capital and/or the stock of knowledge), so the process of factor accumulation to technical process and the behavioural parameters of the model lead to the long-run growth rate. In this section three theoretical perspectives detailing country-specific determinants that influence innovation at the national level but emphasising different factors are discussed. We begin with endogenous growth theory (Romer, 1990, pp. S71-S102), followed by the cluster-based theory of national industrial competitive advantage (Porter, 1990a, 1990b, pp. 84-85), and research on national innovation systems (R. Nelson, 1993, pp. 3-21).

2.1.1 Ideas-driven endogenous growth theory

To overcome the shortcoming of the Solow and Ramsey models, a new set of EGT models have emerged since the mid-80s. The EGT is able to explain sustained growth in the economy by removing the assumption of decreasing returns on accumulated factors and by assuming that savings are completely transformed into investment. The EGT provides a rigorous model in which all variables which impact the flow of new ideas and the size of R & D labour in an economy, in particular the saving rate, the growth rate of the labour supply, the skills of the workforce, and the pace of technological change (Lucas, 1988, pp. 17-18; Romer, 1986, pp. 1002-1037, 1990, pp. S71-S102). In contrast to the earlier neoclassical view, Romer (1986, p. 1003) and Lucas (1988, p. 15) consider technology and technological change as an endogenous determination of the sources of growth. Those variables are not just given, but are partially influenced by organisations, institutions, market structure, market imperfections, trade, government policy, and the legal framework in the EGT

(Aghion & Howitt, 1998, p. 1). Then their effects would provide insights into the causes of different rate of growth which are determined endogenously by agents' behaviour (C. Jones, 1995, pp. 1405-1428; Romer, 1986, p. 1002, 1990, p. S89). Moreover, the continuing concern shows that positive impacts of physical (Arrow, 1962, pp. 155-173) and human capital (Lucas, 1988, pp. 17-27), produce a positive spillover effect on others in the economy, called a positive externality (Romer, 1986, p. 1003, 1990, p. S75).

In addition to the endogenous technology, another characteristic of EGT is competition. According to Marx's idea of competition and technical progress, competition among capitalists increases the accumulation of capital, so that destroying all barriers to the development of capital induces the technical progress as an effective weapon of capital (Marx, 1974). Unlike the neoclassical growth theory, there is an alternative to perfect competition in the NGT models (Romer, 1990, p. S93). Because firms must sell products at prices which are above the production cost to balance the spending of R & D, some imperfect competition in product markets exists to promote private investment in new technologies.

Besides, the NGT is associated with many distortions with research, such as monopoly pricing, inter-temporal knowledge spillovers, congestion externalities, and creative destruction (C. Jones & Williams, 1998, pp. 1119-1135). One kind of distortion is called a classic congestion externality which is the duplication of effort in the research process. An increase in employment of skilled labour reduces individual firms' research productivity, so there are diminishing marginal returns in production of technical knowledge. Then the social marginal product of research may be less than the private marginal product and private R & D investment could be inefficient (C. Jones & Williams, 1998, pp. 1129-1132). Second, creative destruction, which is highlighted by Grossman and Helpman (1991, pp. 43-61; 1993, pp. 70, 335) and Aghion and Howitt (1992, pp. 323-351), is one form of distortion. That is, new ideas may replace old ideas. Firms would overinvest in research and innovators would earn rents on ideas that are not entirely new. Hence, creative destruction has to be careful about the compensation for this ideas and the description of this process.

This section introduced the main characteristics of EGT models; our focus now turns to discussing further developments in endogenous growth models.

2.1.1.1 First generation endogenous growth model

What has become known as the first generation endogenous growth model by Lucas (1988) and Romer (1986) is the sustainable long-term growth from new ideas and there are various factors counteracting diminishing returns to capital. Generally, the amount of human and physical capital devoted to R & D is regarded as a crucial determinant of technological progress (Lucas, 1988, p. 39; Rebelo, 1991, pp. 500-521; Romer, 1986, p. 1033). Therefore, we will now discuss two key approaches to explain sustained, policy-sensitive growth in the economy. First we will focus on human capital formation associated with the work of Lucas; then knowledge accumulation associated with the work of Romer.

2.1.1.1.1 Human capital

One strand of theory extends basic capital accumulation and indicates that persistent growth is obtained by transforming labour from a scarce resource into a reproducible factor – human capital – under perfect competition with constant returns to scale (L. Jones & Manuelli, 1990, pp. 1008-1038; King & Rebelo, 1990, pp. S126-S150; Lucas, 1988, p. 7; Rebelo, 1991, pp. 500-521).

The initial developments of the model are linked to Uzawa (1965, pp. 18-31), who asserts that one sector produces the final good and another sector produces new knowledge. The new ideas are attributed to the labour in the research and education sector, so that the human capital accumulation shifts the production function of the final sector without diminishing returns and produces sustained growth. Hence, accumulation of human capital through technical change acts an essential role in the R & D models.

Later, Shell (1966, pp. 62-68; 1967, pp. 67-85) adopts accumulation of knowledge into economic growth, so the process of production of knowledge depends on the resources allocated to research sector. The greater the resources employed in the research for new ideas, the greater the technical knowledge will be. Shell's model is distinct from Uzawa's, as it assumes that the new ideas (*F*) may be considered as a factor in the production.

$$Y = (F, K, A)$$

Where: *F* and *K* denote the current levels of the stocks of technical knowledge and physical capital, respectively; *A* denotes the current size of the labour force. Following from Solow, Shell (1966, pp. 62-68; 1967, pp. 67-85) also treats technological knowledge as a public input that is provided by the government.

In the one-sector models by Rebelo (1991, pp. 500-521) and King and Rebelo (1990, pp. S126-S150), all inputs in production assume to be accumulative and the accumulation of physical capital acts as a significant role in sustaining growth. Building on the Ramsey model, there is a linear relationship between total output (*Y)* and the process of capital accumulation (*K)* in a constant return to scale production function (the AK model) (Rebelo, 1991, pp. 500-521).

$$Y = AK$$

In the two-sector version in Rebelo (1991, pp. 500-521), the externality is not present and the capital good sector only produces the capital goods. Therefore, the rate of profit is determined by technology. The rate of growth is attributed to the saving-investment mechanism.

Instead of one kind of capital, King and Rebelo (1990, pp. S126-S150) assume that there are two kinds of the accumulation of capital which are real capital and human capital. The rate of profit is also determined by the technology and the growth rate is endogenously determined by the saving-investment equation. Hence, the returns to scale are constant in both models.

In addition, Jones and Manuelli (1990, pp. 1008-1038) allow the accumulation and non-accumulation of factors into the aggregate production function but restrict the impact of an accumulation of the factors of production. Thus, the model consists of labour, capital, and technology, as the Solow model does; however, convex technology shows the marginal product of capital is a decreasing function of its stock.

Different from prior models, Lucas (1988, pp. 17-35) points out that the production of human capital generates a non-rival non-excludable good, so the accumulation of human capital is associated an externality and endogenous growth is positive. Furthermore, human capital replaces the research sector in Uzawa's model, but in both models, the accumulation of human capital depends on knowledge and skills through education (Melnik, 1971, pp. 371-375). Therefore, individuals spend time learning knowledge and skill through education, and then the growth rate of human capital raises the ability to produce goods and services.[7]

As a result, Lucas' model indicates that the savings rate is constant and determined endogenously by the maximising behaviour of the planner or of households. The AK model follows the classical and neoclassical tradition that investment is induced by saving. Even though Lucas' model incorporates externality, it is not essential to ensure sustained growth.[8] In order to ensure sustained growth,

[7] In the education model of economic growth, Lucas (1988) assumed that individuals devote time to learning and live forever. There are no new individuals to replace those who die, so there is no relearning and retraining for individuals. Suppose that individuals allocate time to production and learning. Education accumulation is related to the existing stock of education, time spending on learning and the productivity of learning. Then, human capital grows steadily over time and economic growth is equal to the rate of technological progress (Lucas, 1988, pp. 3-42).

[8] In Lucas's education model, there are some specific assumptions. First, Lucas assumed that individuals live forever, so that there is a constant rate of learning over individuals' lifetimes. However, it is impossible that individuals can live forever. Second, Lucas assumed that the productivity of learning is at a constant rate (Barro, 1990, pp. 103-125). However, Berg (2001, pp. 373-383) indicates that high returns

the following indicates that knowledge accumulation is an alternative approach to the factors of production.

2.1.1.1.2 Knowledge accumulation

Based on the positive effect of R & D on the overall stock of knowledge, a second approach represents that technological progress is considered as an improvement in technological knowledge through R & D expenditure which is incorporated into the new production function (Arrow, 1962, pp. 155-173; Grossman & Helpman, 1989, pp. 1-29, 1993, pp. 1-17; Romer, 1986, p. 1003, 1990, p. S77).

This approach started with Arrow (1962, pp. 155-173), learning by doing was the fundamental contribution of the neoclassical approach to endogenous growth, so work experience is exhibited by the cumulative flow of new investment. In Arrow's model, work experience is represented in the production of new capital goods and knowledge though learning by doing is considered as a public good. Just like Lucas (1988, p. 40), Arrow (1962, pp. 155-173) indicates that there is an unintentional side effect of the production, so that spillovers may occur in the course of investment in physical capital. Under an increasing function of work experience, the innovation induces labour efficiency; that is, each work activity implies learning, so that workers become more productive over time.

Romer (1986, p. 1005) broadened the concept of capital by Arrow (1962, pp. 155-173) and argued that capital not only consists of the accumulation of physical capital goods, but also the investment in knowledge or information by forward-looking, profit-maximizing agent, not capital (Grossman & Helpman, 1993, pp. 35-38). In this initial version of the Romer model, there is a trade-off between consumption today and knowledge that will produce more consumption tomorrow. In terms of research technology, he formalises forgone consumption to produce

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to education are usually associated with low levels of education and in low-income countries.

knowledge and there is no depreciation for knowledge. Therefore, research technology is determined by forgone consumption in research (*I*) and the firm's current stock of knowledge (*k*).

$$\dot{k}_i = G(I_i, k_i)$$

Then the continuing accumulation of the inputs generates positive externalities, so growth can be sustained by spillovers from investment in physical capital to Romer (1986, p. 1003).

In this model, there are usually three sectors: a final good sector, an intermediate sector and an invention sector. The invention sector produces designs of new intermediate products, so that new ideas affecting the technology produce intermediate goods available in the next period.[9]

Based on learning by doing which leads to knowledge expansion, the initial version of Romer's (1986, p. 1019) model indicates that knowledge is assumed to be the only capital good in the production of the consumption good and other factors are in fixed supply. A percentage increase in the stock of ideas results in a proportional increase in the productivity of the idea sector. Therefore, the high level of the capital stock induces more productive firm. It means that the level of R & D activity varies proportionally with economic growth. Furthermore, the overall availability of trained scientists and engineers is important for economy-wide innovation, so that the level of effort devoted to ideas production leads to the growth rate in ideas.

As a result, in a simple endogenous growth model, endogenous technological change and the accumulation of capital are considered as a primary driver in the long run growth. Also, the technology exhibits constant returns to scale at the firm level.

[9] In other words, consumption in the household level is interpreted as leaning by doing. The production function of the consumption good relative to firm i is

$$Y_i = F(k_i, K, x_i)$$

K is the accumulated stock of knowledge in the economy and x_i are all inputs different from knowledge. Furthermore, savings are transformed completely into investment in the capital market, so that investment determines the stock of physical capital available in the next period (Romer, 1986, pp. 1002-1037).

However, Jones (1995, pp. 759-784) indicates that first generation growth models are not consistent with the empirical evidence, consequently a number of second generation growth models were developed in endogenous growth theory.

2.1.1.2 Second generation endogenous growth models

Generally, there are two types of second generation endogenous growth model, which are semi-endogenous by Jones (1995) and Kortum (1997) and Schumpeterian growth models by Aghion and Howitt (1998) and Howitt (1999).

In the current version of the Jones / Romer endogenous innovation model, there are three sectors included, which are a household sector, a government sector, and a business sector (C. Jones, 1995, pp. 759-784; Romer, 1990, p. S79). In order to maximise lifetime utility, a household sector chooses to consume, save, and work. Second, a government sector collects taxes, issues patents, and provides infrastructure (airports, roads and bridges, etc).

Third, a business sector applies quantities of resources to employ and produce output, so that the sector can approach maximum profits. Generally, there are two types of firms in the business sector. One is upstream innovative firms which hire skilled labour to conduct research and produce innovative inputs to sell. Another is downstream final goods firms which hire skilled labour and buy innovative inputs to produce output. The Schumpeterian idea indicates that technological progress is associated with imperfect competition (Schumpeter, 1942, p. 78). In this situation, perfectly competitive market occurs for final goods, capital and labour, but the imperfectly competitive market exists for innovation because of a fixed cost linked to the purchase of new designs. This monopoly power comes from the holding of property rights via the patent system and copyright. Then, monopoly rents on discoveries, so investors can earn reward for new ideas (Kremer, 1998, pp. 1137-1167; Mazzoleni & Nelson, 1998, pp. 1031-1052). The characteristics of different sectors clearly play an important role in the development of these second generation models; we are now going to discuss these developments in more detail.

2.1.1.2.1 Semi-endogenous growth models

Within neoclassical macro-dynamics, the scepticism has given rise to the emergence of semi-endogenous growth theory which is promoted by Jones (1995) and Kortum (1997). In models of this genus, technical progress itself is endogenous, but exogenous population growth drives long-run growth not technological accumulation. Therefore, Jones (1995, pp. 759-784) demonstrates that a given percentage increase in the stock of ideas would not generate a proportional increase in the productivity of the ideas sector, so that it is potential to eliminate the possibility of sustainable long-term growth.

2.1.1.2.2 Schumpeterian growth models[10]

On the other hand, the Schumpeterian models of Aghion and Howitt (1998) and Howitt (1999) consist of unintentional effects, called externalities. This spillovers effect of knowledge increases R & D investment and growth permanently[11].

According to Arrow's (1962) model, the learning by doing stimulates workers and managers to increase investment (Grossman & Helpman, 1993, pp. 35-36). An increase in experience leads to an increase in productivity and there is a positive production externality. Several other models also show technological progress is based on some production externality. For instance, Kaldor (1970) and Shell (1966)

[10] Schumpeter (1942, pp. 81-86) highlights the innovative activity of profit-motivated entrepreneurs under the process of creative destruction. Each firm seeks to gain profit in the market through superior products, new techniques, new markets, or efficient methods of production. Because the creative innovation of its competitors destroys its monopoly, the firm's gain is temporary. This constant technological progress leads to the innovation and is the source of the economic growth.
Then Schmookler (1966, pp. 1-17) reviewed Schumpeter's interpretation of technological progress and found that new technology doesn't just happens exogenously to the economic progress.

[11] Spence (1984, pp. 101-122) indicated that an increase in industry R & D investment is related to spillovers. Katz (1986, pp. 527-543) also indicated that the magnitude of spillovers is a significant determinant of R & D activities and industry output production.

disclose technological knowledge is considered as a public good and the function of production is characterised by increasing returns to scale.[12]

Subsequently, Romer (1990, p. S93) dissatisfied with his initial approach improves his views about the treatment of knowledge, arguing that private investment in knowledge could take place under imperfect competition. He (1990, p. S74) highlights the fact that technological knowledge and other innovative ideas are non-rival and partially excludable goods.[13] In addition, Romer promotes the second aspect of new growth theory which makes the rate of technological change endogenous in two distinct ways. One is the R & D labour market which is the number of ideas workers. Another one is the stock of ideas available to these researchers; that is, the stock of ideas discovered in the past. Even further, the second version shows that technological progress consists of not only the accumulation of new ideas but also immaterial goods.

Following the pioneering contribution of Romer (1986) and Lucas (1988), Aghion and Howitt (1992) argue that innovation, which results from the R & D in the profit-rent-seeding firms, is considered as a source of economic growth. They focus on technical progress which improves the quality of products and refer to the idea of creative destruction from Schumpeter (1942, pp. 81-86), and then there is a new production model, called neo-Schumpeterian. In this innovation-based growth model, the quality improvement of R & D leads to a boost in the profitability and

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[12] Kaldor (1967) assumed that there is a positive relationship between the productivity per worker and gross investment in the technical progress function. Only new (gross) investment would increase productivity.
Shell (1966, pp. 62-68; 1967, pp. 67-85) treats the level of technology as a public input provided by the government. The level of technology receives no compensation, so it is free to exploit the stock of technology. Then, Shell (1973) indicates that externalities are present in the production technology and are associated with the increasing returns to scale.
See the books by Grossman and Helpman (1993, pp. 22-42) and Aghion and Howitt (1998). Shell (1966, pp. 62-68; 1967, pp. 67-85; 1973) and Romer (1986, pp. 1002-1037; 1990, S71-S102) introduce technological knowledge into the growth theory with production externalities and increasing returns to scale to analyse the role of industrial organisation in growth, the dependence of growth on initial conditions and other significant macro problems.

[13] A non-rival goods is the goods that one firm does not preclude other firms to use. A partially excludable goods is that knowledge and/or ideas can inhibit others from using them (Romer, 1990, pp. S71-S102).

further attracts additional resources into R & D. R & D firms can grant a monopoly power to get profits of selling ideas, so that endogenous growth shows the increasing marginal product of capital. Hence, innovation sustains capital accumulation and economic growth.

As a result, Romer (1990, p. S89) and Grossman and Helpman (1993, pp. 1-18) have treated R & D like other production activities, which automatically convert primary inputs into output, such as knowledge. They assumed that technological change is the force of economic growth, the endogenous technological change is determined by the purposeful actions, and the ideas (knowledge) can be used over and over again without additional cost (Aghion & Howitt, 1998; Crafts, 1996; Grossman & Helpman, 1994). Because non-rival and partially excludable characteristics of knowledge induce increasing returns internal to the firm and imperfect competition (as a result of which firms are able to capture monopoly rents on their R & D activities) (Aghion & Howitt, 1992; Romer, 1990, p. S93), R & D not only increases the overall stock of knowledge in the economy, but also enhances firm's productivity. Hence, an increase in the stock of knowledge contributes to an increase in the rate of growth of technology and then the rate of growth.

2.1.1.3 Summary

While in the Solow model technology is totally exogenous and available, in the endogenous growth model technological progress is driven by R & D. The EGT put aside the basic idea of the neoclassical school which is a correspondence between the quantity of a factor and its price. The focus shifts from material resources to immaterial resource and the initial perspective picks up the thread of the EGT in 1960s. The model not only emphasises the concept of increasing returns to scale which is related to knowledge externalities but also points out how increasing returns incorporate into the growth theory.

Even though a considerable body of research indicates that economic growth is attributed to R & D, many observers stress that inherent uncertainties are connected with industrial research (Grossman & Helpman, 1994). Young (1993) also points out the period of learning-by-doing takes a long time, he doubts the possibility of using new technologies for economic growth.[14]

2.1.2 The cluster-based theory of national industrial competitive advantage

A number of authors have focused on the microeconomic environment which mediates the relationship between competition, innovation, and productivity growth. Started from Rosenberg (1963), he indicates the association between microeconomic environment and the rate of technological innovation and economic growth.[15]

According to Porter (1985, pp. 337-339, 347-348, 376-378; 1990a; 1990b), a variety of cluster-specific circumstances, investment, and policies affect a nation's industrial clusters under technological innovation. He develops the microeconomics-based models of national competitive advantage and industrial clusters, such as the interaction between input supply and local demand, local rivalry, and the industrial support (Porter, 1990a). This microeconomic environment presenting in a nation's industrial clusters influences firms to develop innovation. A strong cluster innovation environment can augment the advantage of the innovation infrastructure. For instance, although France processes a strong infrastructure supporting scientific education and training, national regulatory

[14] Young (1993, pp. 443-472) integrates R & D model (Romer, 1990; Grossman and Helpman, 1991) with learning by doing (Arrow, 1962; Lucas, 1988) and highlights the role of societal institutions. Young assumes that developing inventions are attributed to R & D. patents are existing, experience leads to technological knowledge, but such learning by doing is bounded, and technological spillovers occurs among sectors. Therefore, the growth rates decrease.

[15] The R & D activity clearly depends on the technological and economic environment of the research system. If the research system successfully adapts the changing environment, the new structures for performance of R & D would be strong (Rosenberg, 1963, pp. 217-227).

policies have limited innovation of pharmaceutical during 1970s and 1980s (L. G. Thomas, 1994). Hence, the characteristics of the environment in an industrial clusters shape the rate of private sector innovation.

Later, Porter (2000) categorises four key drivers in the framework. The first motivation is the factor (input) conditions, such as high quality human resources, strong basic research infrastructure in universities, high quality information infrastructure, and an ample supply of risk capital. Like the emphasis of ideas-driven growth theory, the availability of R & D personnel would lead to cluster-specific R & D productivity. A second element is firm strategy and rivalry. For instance, general innovation incentives, like IP protection, affect the competition. In addition, cluster-specific incentives also play a central role of competition, such as regulations impacting products, pressure from local rival, and openness international competition. Hence, local competition among local rivals can stimulate investment in R & D activity. The third determinant is the nature of domestic demand for cluster products and services. The demand for advanced goods and the presence of sophisticated and demanding local customers encourage domestic firms to promote innovation, so that it would raise the incentives to pursue innovations in the universe. The final factor is the association between related companies and supporting industries which leads to knowledge spillovers and scale economies, so that positive externalities spread geographically.

As a result, innovative clusters constitute national competitiveness, so that innovation-based domestic competition stimulates national innovation systems and the level of innovation prospers in an economy.

2.1.3 Research on National Innovation Systems

While the ideas-driven growth models and theories of national industrial competitive advantage incorporate the role of public policies in shaping the rate of innovation, the national innovation systems approach highlights the role of national policy (e.g. IP or trade policy), education, and country-specific institutions (R. Nelson, 1993, pp. 3-21).[16] Since the late 1980s, a new conceptual framework appeared in the theoretical and empirical research developments: National Innovation System (C. Freeman, 1987, pp. 1-54; Lundvall, 2010; R. Nelson, 1993, pp. 3-21). The literature demonstrates that an innovation system is composed of sectors like government, university and industry and their environment. Those organisations contribute to innovative activity in specific nations. Hence those institutions and actors play a decisive role to lead to diverse innovation approaches in specific industries (Dosi, 1988; Edquist & Johnson, 1997; Lundvall, 2010; R. Nelson, 1993, pp. 3-21).

According to Nelson (1993, pp. 3-21), a National Innovation System exhibits those interactions among institutions that determine the innovative performance of national industries. Hence, Nelson discloses the analysis of institutions and the ways that nations have organised their National Innovation Systems. On the other hand, Lundvall (2010) adopts a more conceptual focus on knowledge and the process of learning, such as learning by doing. In this case the National Innovation System is constituted by firms, public laboratories, universities, financial institutions, the educational system, and government regulatory bodies. Those elements interact together in the knowledge, diffusion and the production.

[16] For instance, Lundvall (2010) and his collaborators present the importance of leaning of an institution. Though it is critical that government policy is a discrete area, the collection edited by Edquist and Johnson (1997) advocates to assist firms and organisations to enhance innovativeness, such as the expense of employment. Nelson and Rosenberg (1994, pp. 323-348) indicate the significance of the university system, Merges and Nelson (1990, pp. 839-916) emphasise the importance of intellectual policy protection, Mowery (1984, pp. 504-531) focuses on the historical evolution of the organisation of industrial R & D, and Mowery and Rosenberg (1999, pp. 1-46) highlight the division of labour between industry, university and government for R & D funding and performance.

2.1.4 Summary

The object of this section was to review the field of endogenous growth theory with a view to examining the variety of models. Obviously, different theoretical perspectives emphasise specific factors which play an essential role to motivate R & D activity, allowing a country to generate prosperous new output. As a result, all perspectives not only acknowledge that R & D investment have been pointed out as a major engine of growth but also claim that economic and institutional factors lie behind the pace of technological progress. Based on the theoretical perspectives in this section, the next section is going to depict specific factors that influence R & D investment identified through relevant empirical studies.

2.2 Determinants of research and development

From the relevant literature, it is clear that R & D plays a central role in the process of long-run economic growth. However, it is critical about the drivers of R & D activity. Even though empirical studies investigate the relationship between R & D activity and a growing wide range of variables, different conceptual and methodological approaches tend to consistently emphasise a number of explanatory parameters and offer various insights to the key factors driving the innovation process.

According to endogenous growth theory, there are three key elements in the production of ideas.[17] The first determinant is *human capital* which is dedicated to the production of R & D activity. In this perspective, the conception expands to include other factors that impact innovative activity (Mankiw, Phelps, & Romer,

[17] For instance, in the endogenous theory, Romer (1993, pp. 543-573) represents that poor countries face the problem of technology gaps, called idea gaps. In order to mitigate the idea gaps between nations, government promotes a variety of policies which include in the trade regimes, technology transfer, infrastructure, financial markets, taxation, intellectual property rights and law. Furthermore, Nelson and Pack (1999, pp. 416-436) discussed the Asian miracle and modern growth theory. Although the accumulation of physical and human capital is necessary, the establishment of a policy which stimulates learning environment is more significant for success.

1995, pp. 275-326). For instance, the higher education influences the size of R & D employment and even stimulates R & D activity. The second element is *financial resources*; these consist of the investment in public policy choices, such as patent and copyright laws, R & D tax credits, the antitrust laws, the rate of taxation of capital gains, and the openness to international trade. For example, the potential profit of R & D and the period that the innovator can enjoy the profit are also significant before an old idea is destroyed by further innovation. The final element is *cumulative technological sophistication*. Innovations require current R & D expenditures that are paid for from future profits, so the interest rate determines how future profits are discounted to the present (Aghion & Howitt, 1992, pp. 323-350; Grossman & Helpman, 1993; Romer, 1990, pp. S71-S102). Therefore, the common innovation infrastructure includes those three elements that support innovation activity.

Even though the R & D activity lacks a unifying theory, there are several partial theories discussing the role of various determinants.[18] Later, I specify four factors of R & D activities, which are institutional, social, economic, and organisational factors.

2.2.1 Institutional factors

Institutional factors, which are considered as a set of common habits, routines, established practices, rules or laws, regulate the relations between individuals and

[18] The idea-driven endogenous growth theory (Romer, 1990, pp. S71-S102), the cluster-based theory of national industrial competitive advantage (Porter, 1990b), and research on national innovation systems (R. Nelson, 1993) indicate that country-specific determinants influence innovation at the national level but emphasise different factors.
The concept of national innovative capacity consists of idea-driven endogenous growth theory (Romer, 1990, pp. S71-S102), the cluster-based theory of national industrial competitive advantage (Porter, 1990b), and research on national innovation systems (R. Nelson, 1993). The national innovative capacity evaluates the ability of a country to produce new technology in a political and economic entity, and then reflects fundamental determinants of the innovation process. Because technological opportunities are considered as a basic determinant to conduct the new-to-the-world technology, the national innovation capacity refers to the economic geography and innovation policy. Generally, there are three categories of determinants of national innovative capacity, which are common innovation infrastructure, the cluster-specific innovation environment, and the quality of linkages (Porter & Stern, 2002, pp. 102-118).

groups. Some institutions are created by design, such as intellectual property rights protection, competition policy. Some institutions are evolved over time, like national culture. Those legal conditions, rules, and norms constitute constraints and significantly impact the inclination of innovation in an organisation (Edquist & Johnson, 1997), so that institutions shape the behaviour of firms (Arocena & Sutz, 2000; Edquist & Hommen, 1999).

Since Adam Smith's Wealth of Nations in 1776, economists have been aware that security of property rights is an important stimulus to encourage investment and the accumulation of capital. The role of property rights, the effectiveness of the legal system, corruption, regulatory structures and the quality of governance also have been discussed (Acemoglu, Johnson, & Robinson, 2001, 2002; Chhibber, 1997; Glaeser & Shleifer, 2002; North, 1990, pp. 107-130).

North (1991) defines institutions as human constrains between political, economic and social interaction. There are two types of constraints. One informal constraint consists of customs, traditions, taboos, and conventions. Another formal constraint includes laws, rules, property rights, and constitutions. In the empirical study, North (1990, pp. 92-104) argued that the economic development in Western Europe did not start until the property rights are developed. Hence, the protection provides incentives for researchers and advanced technology, and ultimately economic growth (Aghion & Howitt, 1992; Grossman & Helpman, 1993, pp. 16-17, 200-205; Romer, 1990; Young, 1993).

As a result, non-economic factors are considered as the significant role on economic performance. The following section simply discusses three types of institutional factors, which are the national culture, the openness of the economy, and the patent protection framework.

2.2.1.1 Culture

The adjustment cost is a cost which is related to the introduction of an R & D in an organisation, such as a new physical capital, new process, and new products. According to Hofstede (1980), national culture is considered as the collective software of mind that distinguishes one group of people from another, such as the values and beliefs from the early childhood.

Culture is also assumed to have a profound impact on the R & D investment.[19] A culture in a society or organisation may either foster or inhibit technological development, such as the willingness to face uncertainties and take risks (Foster, 1962; Shane, 1992). Those cultures which value creativity will have a greater number and quality of R & D investment, and the country that reward technical ability and higher education will also prosper R & D activity. Therefore, culture affects the willingness of the people to invest in new technologies in a society, and then culture impacts the adjustment cost and R & D investment.

2.2.1.2 Openness

Starting with Adam Smith and David Ricardo, economists have developed arguments indicating that international trade helps human welfare prosper in a country (Berg, 2001, pp. 327-334).[20] Generally, if one country could purchase a good more cheaply from abroad, this nation would get the profit from comparative advantage. In neoclassical growth models, technological change is exogenous, so it is unaffected by a nation's openness to trade. Based on the standard open economy version of the Solow growth model, trade liberalization can have a temporary, but

[19] For example, power distance defines a general societal norm a value system and measures the interpersonal power between the superior and subordinate (Hofstede, 1984). The low power distance index (PDI) means the strong social mobility and the mobility of the middle class in a nation. To improve the mobility and development, investment in technical skills and knowledge play an essential role. Thus, the low PDI induces the low adjustment cost, and then leads to the high R & D investment intensity in a country.

[20] The argument is that the traditional theory of international trade is *static,* and the theory shows that a country enjoys to trade with others. However, economic growth is *dynamic* in nature. It means that economic growth is an equilibrium *path* over time, not the equilibrium *point* (Berg, 2001, pp. 327-334).

not a permanent impact on the long-run rate of growth.

Based on the Schumpeterian R & D model, Romer (1990; 1993; 1994) further applies the endogenous growth literature and emphasizes the flow of ideas. If governments do not provide protection to domestic producers against foreign industries, the openness would provide the greater access to exchange ideas of new technology or knowledge. The large potential market stimulates the demand for new products and the development of new products. Then, the imports of intermediate product become more productive, and further enhance labour productivity and total factor productivity (Grossman & Helpman, 1993, pp. 115-122).

Applied to the R & D model, the high degree of openness induces the competitive pressure for R & D in international market and the assimilation of the R & D from trade partners (Coe & Helpman, 1995; Engelbrecht, 1997; Gustavsson, Hansson, & Lundberg, 1999). The firm would spend more on R & D expenditures and domestic economy would gain the benefit from R & D activities. Then, the returns to innovation increase and more resources are applied to R & D activity, so the market expands its size. Hence, the productivity and competitiveness of a country depends not only on its own R & D, but also on the R & D activity of trade partners in the universe.

2.2.1.3 Intellectual property rights

One of the inducements to the developments of new products is the patent protection and other intellectual property rights protection (Martin, 2001, pp. 367-373; Tirole, 1988, pp. 389-422). Generally, there are several different kinds of intellectual property rights, such as patent rights, copyrights, trademark rights, geographic indications, industrial designs and so forth. Patent protection would protect ideas, while copyrights protect the expressions of the ideas. And trademark rights protect symbols, marks and names. Usually, but not always, a patent protects the scientific and technological ideas and permit their owners of ideas to extract rents from their use in production, so empirical literatures apply the patent protection to measure its impact on R & D activities and economic growth (Gould & Gruben, 1996; Mansfield, 1994; Mansfield et al., 1977, p. 123).

It is no doubt that the benefits of R & D effort increase the willingness of the firm to invest the product of its R & D activities (Edquist & Johnson, 1997; Tirole, 1988, pp. 389-422; Varsakelis, 2001; Yang & Maskus, 2001). R & D and its diffusion significantly depend on the expected cost and income. In order to create excess economic returns, an innovator invests in R & D to develop new products. Even further, the strong patent protection induces the high monopolistic power of the firm with the high expected revenues.

Under the absence of a patent system, the characteristics of public good of knowledge would impede R & D investment. For this reason, governments intervene into the market by implementing the patent protections. Then, patent systems would reduce uncertainty and protect the results of its R & D investment from imitators' competition.[21] Nevertheless, the market will not be perfectly competitive. With limited monopoly, the inventor can temporarily use new ideas and extract rent from others. Therefore, the patent protections provide not only the incentives for technology creation, but also the opportunities for competitive, efficient diffusion of technology.

2.2.2 Social factors

As the previous section shows different theoretical perspectives on R & D investment suggest that social determinants play an important role in the rise of

[21] To examine the relation between the rights protection framework and R & D investment, the patent rights protection index (PRP) which is taken from Ginarte and Park (1997, pp. 283-301) is one measure of the patent rights protection.

technological progress; such as human capital and knowledge accumulation. The next section takes another look at the factors contributing to the success of new technology or an R & D project, taking social factors into account.

2.2.2.1 Human capital

To stimulate advanced technologies, the host country needs a sufficient level of human capital, which is related to the absorptive capability, to contribute to economic growth (Borensztein, Gregorio, & Lee, 1998). There are many determinants affecting human capital. First, an increase in savings refers to a permanent increase in the growth rate of physical and human capital. Second, the improvement of nutrition and health as well as investment in education and job training will lead to the efficiency of labour.

In the 1960s, human capital theory appeared to supplant the attention on capital accumulation (G. S. Becker, 1962; Schultz, 1961; Weisbrod, 1962). Education and training were becoming crucial determinants of human capital. Later, in the second half of the 1980s, Romer (1989), Dasgupta (1990), Barro (1991) and Grossman and Helpman (1994) has reawakened the attention to human capital in the endogenous growth model, such as the knowledge and training in the labour force. The development of human capital generates a highly educated labour and increases the productivity of labour over time, so the efficient labour approaches the success in the innovation-based growth model (Barro, 1991; Lucas, 1988; Romer, 1989; Uzawa, 1965).

As a result, human capital consists of skills and knowledge which workers acquire through education and training. Nevertheless, in the endogenous growth models or the extensions of the neoclassical model, human capital plays a significant role in the economic growth.

2.2.2.2 Cooperation

The nature of cooperation can be attributed to various types of institutions from universities to cluster trade association. There are a number of different perspectives that discuss cooperation, such as industrial organisation, game theory, transaction cost theory, organisational theory or strategic management. The industrial organisation emphasises competitive motives for stimulating R & D cooperation and concentrates on the flows of knowledge. In the public finance literature, the quality of public services is generally considered as a crucial determinant in the decisions of business location and/or expansion. Public services not only provide direct profits to business but also help to reduce business cost. For R & D investment, cooperative technology program is one type of public services.

For instance, innovation is quite risky in that expected results of innovation may not be obtained and financial funds for new technology may require more than original expectation. To reduce and share the uncertainty and costs, the cooperation between the firm and other external agents to carry out new technology and innovation is necessary (W. Becker & Peters, 1998; Camagni, 1993; Robertson & Langlois, 1995). Especially firms with the lack of knowledge and abilities will seek to cooperate with other firms and agents. Then R & D costs of firms will decline and firms can gain access to the know-how of the partners (Sakakibara, 1997a, 1997b). Although the benefits of innovation will also be divided, the cooperative R & D would assist technology development and application to benefit companies and industries. Hence, cooperative R & D is viewed as a viral option for the survival of the firm today.

2.2.2.3 The quality of cooperation

Based on the cluster-based theory developed by Porter (1990a; 1990b), there is a mutual relationship between the common innovation infrastructure and industrial clusters. Under a given cluster innovation environment, the R & D infrastructure influences the quality of cooperation and even the specific R & D output. For instance, the local environmental regulation and supporting industries would encourage competition in the cluster innovation environment. At the same time, the trained scientists and engineers' access to basic research and policies promoted to develop new technologies also stimulate the environmental technologies cluster. Therefore, the strong linkages between the common R & D infrastructure and industrial clusters would shape R & D investment and economic growth.

2.2.3 Economic factors

This section examines some of the economic determinants that affect the decision on R & D activity; for convenience these are grouped in four major categories: gross domestic product, public funding, fiscal incentives and inflation.

2.2.3.1 Gross domestic product

Although the underlying theory on R & D focuses on supply side considerations, the potential role of demand determinants are also relevant to the R & D investment behaviour of individual firms. For instance, the theory of industrial cluster (Porter, 1990b) argues that R & D investment depends on interactions between input supply and local demand conditions and the competition of industries, but those factors are complicated and immeasurable. To account for these omitted factors, the gross domestic product (GDP) is included in the model to interpret fluctuations in economic health over the sample period. Because of the yearly observations, GDP illustrates the starting point of R & D investment decision which is influenced by the economic situation and then serves as a control variable for time. Its growth may be relevant to determine the market size for future inventions, which in turn is decisive to forecast the profitability of R & D project. Therefore, the investment function exhibits that an increase in GDP generates the output and capital investment would increase.

2.2.3.2 Public funding of research and development

Economists generally argue that some forms of market failure are attributed to the characteristics of public good, such as defence. This market failure exists to lead the private sector not to provide sufficient quantities of R & D. For instance, the costs of new discovery by the private firms are difficult to allocate the social benefits from new technologies. This means that private rate of return to R & D is lower than its social return. In addition, high risk for R & D implies extremely high hurdles and the imperfect capital markets also inhibit firms from investing in R & D project (Griliches, 1998, pp. 1-45; Romer, 1990). This is especially detrimental to small firms for which access to funding is more difficult. For both reasons, R & D activities are likely to be below the optimal level in a competitive framework.

To bridge the gap between the private and social rate of return, Arrow (1962) and Nelson (1959) demonstrate that government support of R & D is the correction of the market failures in the production of scientific and technological knowledge. Government involvement does not only reduce the private cost of R & D but also support firms in understanding the available technological opportunities. Then the cost and uncertainty of R & D would reduce.

Broadly, there are a range of policies consisting of direct financial support and procurement; the next section provides an overview of subsidies and direct procurement in public facilities.

2.2.3.2.1 Subsidies to R & D

Direct subsidies which are accompanied by a government's project are distributed through grants to firms for specific projects or research areas. Such funding could be concentrated in areas where exist a large gap between the social and the private rate of return. The R & D subsidy lowers the private cost of the project, so the subsidy may turn an unprofitable project into a profitable one by the firm. In addition, R & D subsidy can reduce the fixed costs of research facilities (labs), and then it can motivate the probability of undertaking R & D activity. Hence, the R & D subsidy can stimulate current and future private R & D expenditures.

Comparing with fiscal incentives for R & D activities, subsidies are likely to be captured by firms with low income taxes, so subsidies should not influence the tax coefficient. Although a tax-based subsidy seems the market-oriented response and leaves the private sector to make the choice of conducting R & D programs, there are still several drawbacks to subsidy. Some empirical evidences indicate that crowding-out effect does exist; that is the substitution between private and government funded R & D (David & Hall, 2000). Because of high costs of hiring additional R & D personnel, the firm may lean to quit a profitable project. Then the lobbying for subsidies occurs and firms would apply the increased direct government funding for industrial R & D projects to reduce their own cost. Therefore, the subsidised project may crowd out non-subsidised projects and companies may also reduce their contribution to net R & D spending as a response to the public subsidy (David & Hall, 2000; David, Hall, & Toole, 2000).

2.2.3.2.2 Direct procurement or production in public facilities

The direct procurement in public facilities involves the performance of public research institutes and laboratories. Here we introduce two channels that foster the links between public and private sector R & D.

The public sector can conduct basic research and make the result publicly available. Then the public sector R & D lowers the cost of research for the industry and provokes private sector R & D. For instance, university research has been regarded as an essential source of knowledge, equipment and instrumentation and methodologies for R & D researchers. Therefore, the public sector R & D acts as a complement to the private sector R & D.

On the other hand, the public sector R & D can act as a substitute to the private sector R & D. Under scarce high-skill labour, university and government research organisations require high-skilled human resources, so the availability for private sector will reduce. Furthermore, Goolsbee (1998) indicates that public sector R & D in the United States significantly raises the wages of scientists and engineers. An increase in its unit price may also crowd out the growth of R & D volume.

2.2.3.3 Fiscal incentives for R & D

Our focus now shifts to different types of fiscal incentives. Generally, fiscal incentives for R & D can identify into various forms, such as corporate income tax rates, R & D tax credits and so on. First, the changes in tax structure often affect agents' behaviour. An increase in corporate tax rates distort the relative value of resources and lower the net rate of return to private R & D investment. Then, R & D activities are less attractive and the rate of growth declines. Therefore, taxes on investment and income have a detrimental impact on investment activities and economic growth in an economy.

Second, R & D tax credits can support firms to increase financial resources which are committed to technological innovation (B. Hall & Reenen, 1999). This level of R & D tax credit is considered as an indirect subsidy does not distort the relative price of investment. That is tax credits are deducted from the corporate income tax, so an increase in R & D tax credits lowers the user cost of capital and R & D investment becomes more competitive. Then, tax credits will stimulate further research on R & D. Therefore, tax incentives have a potential to encourage R & D investment, and then contribute to economic growth and social welfare.

Comparing R & D subsidy with fiscal incentives, fiscal incentives can reduce the cost of R & D, and direct subsidies can raise the private marginal rate of return on R & D investment. Second, due to the uncertainty of knowledge creation and the tendency of states to reward lobbyists and bureaucrats, government will fail to implement the optimal subsidy policy and rely on fiscal incentives to motivate business R & D. In the face of the gaps between the social and private return, private sector firms will use tax credits to first fund R & D projects with the high private rate of return, so that fiscal incentives allow the private firms to choose projects. With less government interference in the marketplace, fiscal incentives can apply to the desired sector or research project. As a result, fiscal incentives can be more effective in stimulating long-term R & D expenditures than direct R & D subsidies. Moreover, tax incentives can be less costly and less burdensome than R & D subsidies.

In an effort to increase the level of R & D, it is clear that the value of tax credits increases with a marginal tax rate of a firm, so there is a positive relation between a firm's tax rate and R & D expenditures. Nonetheless, some economists have been sceptical of the efficacy of tax incentives. First, fiscal incentives for R & D often involve substantial sums of taxpayers' money, so it is critical that R & D is not very sensitive to changes in its (after tax) prices (Mansfield, 1986). Also, Griffith et al. (1995) are sceptical of relabeling other expenses as R & D.

Furthermore, as firms expand R & D investment related to tax incentives, firms are likely to pursue the projects with high social rates or returns in the short-run. Then the expansion of private funding will not support the long-run project and the research infrastructure investments.

There is little doubt that tax policy is a key primer in motivating R & D investment. How to measure the impact of fiscal incentives, is however not as clear.

Empirical studies have adopted a range of different methods. The next section details two key approaches: *user cost of R & D* and the *B-index*.

2.2.3.3.1 User cost of R & D

The overall generosity of R & D tax incentives can be computed by the annual cost of performing R & D, which is R & D user cost of capital. Based on the neoclassical approach to investment behaviour, the optimal combination of factor inputs should be a function of the relative prices. It means that the optimal capital stock and investment are associated with the price of capital. To maximise the profits, firms thus seek to achieve the desired stock of capital which is dependent on the level of output and the user cost of capital.

Following the seminal papers of Jorgenson (1967), some authors use the neoclassic model of the investment based on the traditional equilibrium relationship between the marginal productivity of the capital and the real user cost of capital. For instance, Hall and Jorgenson (1969) proposed to measure the impact of corporate income taxation on the price of investing in R & D. Generally, the R & D tax credit is applied against corporate income tax liability so the effect of R & D tax credits is associated with the corporate income tax rates. In Hall and Jorgenson's (1969) study, the methodology, consisting of tax credit rates, depreciation allowances and integration of personal and corporate income taxes, derives the pre-tax real rate of return on the marginal investment project that is required to earn a minimum rate of return after tax. For a given level of the other parameters, the rate of R & D credit proportionally affects the user-cost of R & D. The tax credit reduces the after-tax price of R & D as a resource input and makes R & D more competitive with alternative investment, so the firm increases its usage of R & D. Thus, the R & D credits may create added incentive for R & D investments as the user-cost of capital decreases.

Even though the user cost of R & D model is preferable because it is grounded in economic theory and the price response of R & D investment can be estimated directly, there are some weaknesses existing. One methodological issue is the simultaneity between the R & D investment and the tax price a firm faces. Furthermore, as described above, the user cost of R & D is a composite measure so the visibility of policy effects is low.

2.2.3.3.2 B-index

Alternatively, the generosity of tax incentives for R & D activity can be computed by the B-index (Warda, 1996, 2002), which is a composite index measured as the income value before taxes to cover the initial cost of R & D investment and the corporate income tax. If the B-index is high, R & D projects would be profitable and be undertaken, so R & D investment rates are high. Thus, the more intensive R & D countries have the less generous R & D tax support system.

Nonetheless, the B-index method simplifies some assumptions. First, it assumes the same interest rates across nations. Second, there is no difference in the international definition of R & D for tax purposes. Third, other indirect tax incentives are ignored, such as commodity taxes, property taxes, and capital gains taxes. Fourth, countries with high corporate tax rates will have high tax incentives to reduce the after tax cost of R & D. On the other hand, countries with low corporate taxes will have little need to implement tax incentives. Thus, the B-index applies to large corporations because only firms with high corporate tax rates have sufficient taxable income.

2.2.3.4 Inflation

In general, most developing countries spend more than revenue from taxation and need to borrow money domestically or internationally. One solution is to borrow money from domestic market, but it may prompt an increase in real interest rates and private investment would decline. Besides, an alternative way is to print money, but overreliance on money creation leads to high inflation.

In economics, inflation is an increase in the overall price level of goods and services in an economy over a period of time. Started from earlier classical economy, David Hume and David Ricardo examine a currency devaluation affects the price of goods.[22] Then, the optimal growth framework indicates that inflation lowers real interest rates and then reduces saving as well as investment.[23] Because some of inflation costs consist of the average rate of inflation and others relate to the variability and uncertainty of inflation, many central banks think inflation is costly. Therefore, in recent years, central banks have placed increasing emphasis on price stability.[24]

At the firm level, inflation plays an essential role of investment because inflation increases the cost of capital. First, the tax deductions are related to the purchase price of the investment good. An increase in the rate of inflation drops the real value of tax deductions and the user cost of capital increases. Second, a firm's cash flow situation is crucial for investment project (Hubbard, 1997). The increasing inflation rate raises the nominal interest rate and lowers the real value of debt. Then, the accounting profit generated from the project may not exceed the interest payment, and firms may not borrow money to invest even if the project is

[22] The greater variability of relative prices, which results from the inflation, leads to purchase fewer goods and services by each monetary unit. This erosion in the purchasing power of money represents a decrease in the real value of money (like currency) and other monetary items over time, such as loans and bonds. The risk of losses by holding money is getting higher (Parks, 1978, pp. 79-95).

[23] Individual and firms will divert resources away from productive activities toward other rent-seeking activities that can reduce the high costs of inflation. That is, people will maintain low real balances and spend excessive amounts of time in cash and portfolio management instead of in productive activities. A reduction in the labour available for production decreases the productive activities and the rate of growth (Mundell, 1963, pp. 280-283).

[24] Recently, Stanners (1993, pp. 79-107) focuses on the belief that zero or low inflation plays an essential role for high and sustained growth. Today, most economists favour a low steady rate of inflation. In order to keep the rate of inflation low and stable, monetary authorities control the size of the money supply though interest rates, banking reserve requirements, and open market operation.

profitable. Therefore, inflation reduces real balances and the private marginal return of capital, so that there is a direct negative impact on the rate of return. Then, labour demand will also decline.

In addition, the uncertainty about future inflation may deter the propensity of investment and saving (Bulkley, 1981) because it is difficult for companies to budget or plan in the long run and inflated earnings push taxpayers to pay higher income tax.

On the other hand, Keynesians disclose that nominal wages adjust downward in the labour market and inflation would reduce the real wage, so that inflation is good for the economy to reach equilibrium faster. Furthermore, low inflation can mitigate the severity of economic recessions. Inflation reduces the real interest rate of debt and leads to debt relief, so the labour market is able to adjust more quickly in a downturn.

2.2.4 Organisational factors

According to the organizational behaviour/organizational theory literature in the economics literature, there are various organizational characteristics affecting R & D investment, such as management stockholding, capital intensity, and business diversification and capital structure. Even though some evidences from empirical studies show the relation between the organizational variables and R & D activity has failed to reach consensus in the private sector, it is clearly that modelling R & D activity as a function of organizational and other variables provides a more precise estimate of the effects of the R & D tax credits on R & D investment. Therefore, the next section focuses on organisational characteristics, identifying five key categories.

2.2.4.1 Size / Sales / Output

Schmookler (1966, pp. 104-164, 196-215) and Griliches and Schmookler (1963) argue that research effort is a function of expected market size. It means that the private return to R & D varies directly with volume of output or the size of the market. Usually, large firms possess a knowledge base built from previous R & D activity, so those firms are able to absorb such capabilities and carry out new research activity (Kamien & Schwartz, 1982, pp. 31-48). Furthermore, large sized firms are also available to achieve cooperation under a quantity of advantages, such as financial resources and qualified staff, external scientific and technological networks, commercial resources, etc (Rothwell & Dodgson, 1991). On the contrary, the lack of own knowledge base results in the absence of technological and research abilities, so that small sized firms have limited resources to undertake cooperative activity with other firms or agents. As a result, the size of market is positively correlated with R & D effort.

Similar to the size of market, the net sales of firms or the volume of output also produces the same effect on R & D activity. Sales can provide a budget from which discretionary expenditures such as R & D are made (Kamien & Schwartz, 1982, pp. 49-104) and even the future sales are attributed to the current R & D investment (Schmookler, 1966, pp. 196-215). In addition, firms' output may influence R & D activity. Output can be considered as firms' net sales, which are related to firm size, so that output is also intended to account for variation in R & D spending. Therefore, higher size/sales/output is positively associated with R & D expenditure.

2.2.4.2 Financial structure

According to microeconomic theory, governments can stimulate private R & D spending and spur economic growth by reducing the marginal cost of capital

(MCC) and/or raising the marginal rate of return (MRR) on private R & D investment. A change in the relative prices of factors of production is a spur to R & D investment, so the investment decisions of corporate managers depend on the availability of funds for investment.

Starting with Schumpeter (1942), economists suggest that financial resource is a prominent factor for innovation (Branch, 1974; Grabowski, 1968; Himmelberg & Petersen, 1994; Kamien & Schwartz, 1978; Spence, 1979; Switzer, 1984) because establishing a R & D programme is costly and requires large amounts of money to be undertaken. Besides, R & D project involves significant sunk cost and its revenues are likely to be raised only after a rather long period, so financial constraints may impede the decision of R & D spending.[25] Broadly, there are four sorts of financial structures existing among the empirical studies; our focus now turns to illustrating their relationships with R & D investment.

2.2.4.2.1 Tobin's Q

The Q theory is the foremost theory used to explain cross-sectional investment behaviour (Poterba & Summers, 1983; Tobin, 1969). Tobin (1969) defined marginal q as the ratio of marginal benefit to marginal cost of installing an additional unit of a new investment good. It means that a profit-maximizing company will invest in R & D activities as the marginal benefit of investing exceeds the marginal cost. The costs of new investment consist of the access to other external capital sources (debt), access to internal capital sources (operating cash flow), and corporate taxes. In addition, the benefits of investing include future market opportunities which are measured by the firm's stock return and tax tradeoffs.

[25] In economics, sunk costs represent the money already spent and permanently lost, so sunk costs may be incurred if an action is taken (Arkes & Blumer, 1985, pp. 124-140).

As the installed capital has a high value in the market, the higher Tobin's Q and benefits would raise more resources per share in the firm and increase the investment in R & D. Hence, firms' q-ratios are related to R & D spending in the presence of the R & D tax credit and further prosper the economy.

2.2.4.2.2 Cash flow

The second financial variable - cash flow - contains information about expected future profitability and may be relevant for R & D investment decision (Kamien & Schwartz, 1982, pp. 95-98). According to neoclassical theory, the present value of expected cash flows represents to measure the cost of capital. Higher cash flow leads to a reduction of capital cost, so that a profit-maximizing firm will invest in the additional R & D investment. Therefore, the cash flow from operations determines firm's ability or incentive to invest in R & D.

For example, Myers and Majluf (1984) have argued that managers are more likely to finance projects internally, less likely to raise outside debt because of the lower cost of internal finance. Thus, internally generated operating cash flow is the most likely source of R & D capital. Furthermore, Berger (1993) discloses that cash flows can control firms' ability to expand resources on R & D programs. Low cash flows may throw budgets into disarray, distract managers from productive work, deter R & D expenditure or delay debt repayments.

2.2.4.2.3 Leverage

In addition to cash considerations, the third variable that may constrain investment in R & D is the degree of financial leverage used by each of the firms (B. Hall, Berndt, & Levin, 1990). In most studies, leverage is defined as firm's debt to assets ratio for financial reporting purposes. It is clearly that R & D activity is an intangible and firm-specific asset. When firms face possible financial distress, managers may consider the level of current income to evaluate spending decisions. Hence, the high debt ratio would impede R & D spending.

2.2.4.3 Lagged R & D

Among different organisational elements, lagged R & D expenditures are likely to be considered as a factor affecting R & D expenditures because of the existence of adjustment costs (J. I. Bernstein & Nadiri, 1982; B. Hall, Griliches, & Hausman, 1986; Himmelberg & Petersen, 1994). First, the adjustment costs consist of the expense to hire and fire highly qualified labour, and build laboratories. In order to promote R & D, it is necessary to increase substantial quantity of firms' R & D infrastructure in any particular year. Second, because it is difficult to assimilate large percentage increases in R & D staff, there are often existing substantial costs in expanding too rapidly. Third, R & D projects can span more than one year and it is uncertain to measure how long the expenditure of R & D level is maintained. As a result, adjustment costs are significant when there is a sustained commitment to R & D.

To control for the prior year's R & D expenditure, most empirical studies introduce lagged R & D expenditures to distinguish short-run and long-run effects. For example, assumed that prior research identifies a number of non-tax factors, Hall (1993) and Berger (1993) use the level of R & D expenditure as the dependent variable and controls for firm-specific prior R & D expenditure levels. Those studies believe current period R & D investment decisions benefit from prior year's activities. Therefore, the prior year's R & D spending for each firm acts as an important determinant in conducting the new investment. And the positive coefficient on the lagged R & D stock variables indicates that firms performing R & D continue to do so.

2.2.4.4 R & D intensity

Arrow (1962) points out new economic knowledge plays a significant role and argues that knowledge spillovers are crucial in highly R & D intensive industries. A firm's propensity to conduct research is done on the basis of the industry R & D intensity, or R & D-sales ratio. Similar to lagged R & D, R & D intensity has been controlled for in precious research and creates new economic knowledge. For example, compared to services and agricultural exports, manufacturing exports are relatively technology-intensive. Generally, the inherent R & D intensity of the industry structure is modelled by the share of high-tech manufacturing exports in total manufacturing exports. If a country is specialised in industries characterised by a high degree of R & D intensity, the demand of aggregate R & D expenditure will be high. Therefore, the R & D spending is expected to be higher as the inherent R & D intensity of the industry structure is greater.

2.2.4.5 Capital intensity

Another variable that may influence firms' decisions concerning R & D investment is capital intensity measured by a firm's ratio of capital to labour. Among the empirical studies, the relationship between capital intensity and R & D investment is doubtful.

R & D is stimulated by the ability of the firm to assimilate new technology in the production process. As capital intensity increases, the cost of R & D rises less than in proportion to the equilibrium flow of profit. Then R & D and growth both increase. For instance, Freeman and Medoff (1980, pp. 1-43) indicate that more capital available for each unit of labour, the greater the labour productivity and firm productivity.[26] Acs and Audretsch (1987) further demonstrate that capital-intensive

[26] Comparing a capital-intensive firm and a labour-intensive competitor, the firm may have lower average costs of R & D investment than the competitor. Then the industry may exhibit greater efficiency than its competitors (R. Freeman & Medoff, 1980, pp. 1-43).

industries tend to promote the innovative advantage in large firms. Thus, growth and capital intensity are positively associated with innovativeness.

On the other hand, Goel (1990) indicates that R & D and labour are substitute inputs into the production process while capital and labour are complements in production, so R & D intensity is a decreasing function of capital intensity. Furthermore, high capital intensity impedes the entry of new, small and innovative firms, so there is a significantly negative impact of capital intensity for small firms' innovation not large firms (Mansfield et al., 1977, pp. 68-86; Van-Dijk, Den-Hertog, Menkveld, & Thurik, 1997).

3. Methodology

3.1 Meta-analysis

In a standard regression, the parameter (β) is the estimate of the impact of the independent variables on the dependent variable. Because every study possesses different characteristics, the aim of meta-analysis is to examine whether the independent variables of studies influence the results.

Glass (1976, p. 3) is one of the pioneers of meta-analysis. He states:
"Meta-analysis refers to the statistical analysis of a large collection of results from individual studies for the purpose of integrating the findings. It connotes a rigorous alternative to the casual, narrative discussions of research studies which typify our attempt to make sense of the rapidly expanding research literature."

Typically, meta-analysis is a quantitative technique to summarize and evaluate the available empirical parameters (estimates) on a particular issue (Farley & Lehmann, 1986; Glass, McGaw, & Smith, 1981; Rosenthal, 1987). That is meta-analysis establishes guidelines to review, integrate, and synthesise studies examining similar research questions. Then, it can detect whether consensus conclusions are emerging in the studies and whether differences in results across literatures (Cooper, Hedges, & Valentine, 2009). Therefore, the goal of meta-analysis is to detect the existence of an association among the variables of interest, the estimation of the magnitude and the statistical significance of such an association. Moreover, the aim of meta-analysis is to detect any variables which serve to moderate the association (known as a moderator variable).

3.1.1 Strengths of meta-analysis

The conventional review procedures of meta-analysis heavily rely on qualitative summaries or vote-counting on statistical significance. That is to summarise the significance or non-significance among the individual study results as well as attempt to organise study results in order to obtain an effect size. Comparing with the traditional literature review, some papers (Lipsey & Wilson, 2001; Rosenthal & Dimatteo, 2001; Wolf, 1986) have indicated that meta-analysis has some potential advantages.

First, meta-analysis is more systematic to analyse the previously obtained research results. Although the studies have the different specification, data and methodologies, meta-analysis documents each step and opens the analysis to scrutiny. By making the process of research explicit and systematic, meta-analysis clearly compare the different studies in a systematic way. Second, meta-analysis is more objective than the traditional literature review. By encoding the magnitude and direction of each relevant statistical relationship in a collection of studies, the selection of studies minimise the subjectivity in traditional reviews. The effect sizes constitute a sensitivity of reported findings and meta-analysis makes the selection process verifiable. Thirdly, meta-analysis can include non-sampling characteristics as moderator or predictor variables in a meta-regression model. The systematic coding of specific characteristics among studies permits an analytically precise examination of the relationships between findings and study features. Then meta-analysis can generate synthesized estimates. Fourth, meta-analysis is more powerful than the vote-counting in coming up with the right conclusion (Light & Smith, 1971).[27] Under the systematic coding procedures and a computerised database, meta-analysis has the capability to detect the relationships between the reported findings and study characteristics, and further cover large numbers of studies.

3.1.2 Criticisms of meta-analysis

On the other hand, this approach has not been free from criticism and Glass et

[27] In the vote-counting methods, reviewers sort the results of individual study into positive significant, non-significant, and negative significant categories. Hedges and Olkin (1980, pp. 359-369) have demonstrated the procedure power decreases as the number of studies increases. Furthermore, there is a high probability that vote-counting method fails to conclude a positive effect even the result should be positive. Because of the poor statistical properties, the vote-counting approach is no longer recommended.

al. (1981) have grouped these criticisms into four categories.

The first crucial issue is publication selection which published estimates might be a biased sample of all research conducted because editors, reviewers, authors or researchers have a preference for statistically significant results. It can happen when the insignificant results are more likely to be rejected for publication, and then the biased meta-analysis results will be found.

The second problem is concerned with the conclusions by comparing and aggregating studies which are using different measuring techniques, definitions of variables, and subjects among the studies. For example, elasticities may be different in time horizon (short- and long-run elasticities) and different methods. Because of the differences, the elasticity estimates are incomparable.

Third, the heterogeneity exists among studies because results from poorly designed studies are included with results from good studies.

Fourth, as the observations are derived from the same data and the multiple results from the same study are used, the results will appear more reliable than they really are. Then, the problem of independence of the observations is obvious.

To address these criticisms, this study therefore adopts the technique of multiple sampling by including all comparable effect sizes reported by each primary study. Meta-regression analysis (MRA) aims to relate the size of effect to study characteristics. It is the better measure to see through the murk of random sampling error and selected misspecification empirical effect. More detail on MRA is provided below in Section 3.2. Before applying MRA, the next section discusses the development of meta-analysis.

3.1.3 Meta-analysis in practice

As a research method, meta-analysis has a strong position in the behavioural and health science areas, such as medical, psychology, science and education research, especially in medicine. However, it had not been favoured in economics.

The early meta-analysis contributions in economics were introduced in environment economics (Carson, Flores, Martin, & Wright, 1996; Loomis & White, 1996; J. Nelson, 1980; Schwartz, 1994; V. K. Smith & Huang, 1993, 1995). The interests consist of the tourism multipliers, air pollution valuation, risk and value of life, pesticide price policy, travel time savings and transport externality and policy issues.

Now the concept of meta-analysis perform in other fields in economics, such as labour economics (Ashenfelter, Harmon, & Oosterbeek, 1999; Card & Krueger, 1995; Doucouliagos, 1997; Groot & Brink, 2000), industrial organisation (Button & Weyman-Jones, 1992, 1994; Doucouliagos, 1995; Fuller & Hester, 1998; Jarrell & Stanley, 1990; Sinha, 1994a, 1994b), transportation economics (Button, 1995; Wardman, 2001), and marketing (Brown & Stayman, 1992; Peterson, 1994; Peterson, Albaum, & Beltramini, 1985; Sheppard, Hartwick, & Warshaw, 1988; Verlegh & Steenkamp, 1999).

In addition, the application of meta-analysis is further explored in the field of macroeconomics (Florax, Groot, & Mooij, 2002). To evaluate policy impacts, the meta-analysis incorporates all available empirical knowledge about the relationship. Then, the meta-analysis can represent a better calibration of policy models and obtain the improved consensus estimates for policy makers. Therefore, it is clear that meta-analysis is catching up throughout various areas of economics.

Since the primary empirical studies are abundant and summary statistics are clearly defined, meta-analysis can easily provide a good summary indicator from a range of literatures, and then be more effective to predict the magnitude of effects or values of comparable sites. As a result, the meta-analysis collects all the available information on a specific relationship and comes up with summary statistics that can benefit policy makers and future research.

3.2 Meta-regression

As the precious section indicates MRA is an ideal quantitative methodology to objectively examine the diversity of results among different literatures. To put it in plain terms, MRA is thought of multiple regression analysis and has been developed to analyze the multidimensional nature of the research process (Stanley, 2001; Stanley & Jarrell, 1989). It is not only aimed to understand the research process itself, but also seeks to map the sensitivity of reported findings to the study characteristics, such as the choice of data, estimation technique, econometric models, and other issues. Then, researchers can apply MRA to control for the potential sources of biases. They use that information to uncover various interaction effects on the variable of interest and investigate the statistical heterogeneity among economic results of multiple studies. Therefore, MRA will display diversity in the results from the literatures, and the result may not be unduly impacted by researcher biases.

3.2.1 The theory of meta-regression analysis

In this case, my review uncovered some individual researchers doubt the efficacy of R & D tax credits on R & D activities among the existing literature. A review of the literature allows me to investigate how findings on the effect of tax credits on R & D investment can be expected to differ and why. First, suppose that a sufficiently large number of statistical regression tests exist in a literature and that they take a sufficiently common form. Formally the empirical studies estimate the following equation:

$$\left|R\,\&\,D\right| = \beta_0 + \beta_1 * TAX + \beta_2 * Z + \varepsilon \quad (1)$$

Where: the dependent variable is R & D investment, TAX is the R & D tax credit, Z is a set of inputs and control variables, and ε is an error term. According to those empirical studies, the main coefficient of interest is an estimate of the impact of tax credits on R & D investment (β_1). Even though each study provided an estimate of the effect of interest and a standard error for this estimate, the usual test of interest relates to whether β_1 is significantly different from zero (a two-sided *t*-test).

Although equation 1 takes a common basic form, these studies have differed from one another along many dimensions. Different researchers might present specific estimates of the effect of tax credits on R & D expenditure with and without a particular control variable. Some cross-country growth regression studies include some measures of R & D tax credit as an explanatory variable. Some R & D investment studies include R & D tax credits as a control variable, even though the literatures primarily test other determinants of R & D investment. However, MRA can support considerable statistical power to explain the variation in tax credits effects from the existing literature.

MRA has been suggested by Stanley and Jarrell (1989) as a means of summarising more accurately regression results across studies, such as those investigating the relationship between R & D tax credits and R & D activity, and making generalisations from the available empirical evidence. Then, I can estimate the MRA taking the form:

$$T_1 = \beta_0 + \beta_1 * MV + \varepsilon \quad (2)$$

where the dependent variable (T_1) is the reported estimate of the effect of tax credits on R & D investment in the studies, β_0 is the "true" value of reported estimate, β_1 is the coefficient of the biasing effects of study characteristics, MV is the moderator variables which measure relevant characteristics of an empirical study, and ε is the error term.[28]

[28] Stanley and Jarrell (1989, pp. 161-170) note that the MRA estimation using ordinary least squares may result in errors that are heteroscedastic. Because different data, sample sizes, and independent variables of empirical studies may result in unequal variances, generalized least squares (GLS) are used to correct the problem in the equation.

Clearly the constant intercept term in model 2 (β_0) has an important interpretation in this context. The intercept from equation 2 may be interpreted as a baseline effect. It is the constant term represents the average estimate predicted by the model when all of the dichotomous meta-independent and continuous variables are zero.

In addition, different meta-independent variables, called moderator variables, must be used to control for any biasing effects of study characteristics, so that MRA would provide more information on the moderator variables. Clearly, those variables measure relevant features of the empirical survey and aim to compute a weighted average of estimated parameter coefficients. Their slope coefficients (β_1) are the parameters of primary interest in this paper. Those moderator variables not only affect the direction but also the strength of the relationship between an independent and dependent variables.

For instance, different researchers might present estimates of the effect of tax credits on R & D expenditure with and without a particular control variable or by applying a different specification. They could measure R & D investment and tax credits in different ways. They could vary the set of control variables. Furthermore, they could make different assumptions about the error term by assuming that it is correlated with some measures of tax credits or an element of control variables. They could select different countries and different time periods, or structure their data as a panel or cross-section. The slope parameters from equation 2 (β_1) therefore, indicate how different methodologies lead researchers to obtain results.

Although this literature search was intended to be thorough, it is impossible to guarantee that all relevant studies were discovered. MRA is not perfect and this may be due to the search constraints or the persisting problem of publication bias. For instance, certain similarities exist between the reviewed studies, so that the replication of empirical results exists. In addition, there is a tendency for journal editors to publish articles only with statistically significant findings, while null findings remain unpublished. Therefore, specifications restrict the sample based on one of the characteristics of the study. Each of these regression specifications serves as a check on robustness.

3.2.2 The practice of meta-regression analysis

My main hypothesis is straightforward: if the tax credit reduces the cost of research so the net present value of returns from the R & D are greater than zero, the credit should induce higher levels of R & D than in absence of any tax credit (holding other factors constant). To resolve differences that arise from the heterogeneity among a range of empirical studies, the meta-analytic techniques adopted to examine the effect of tax credits on R & D activities in this study are detailed as follows.

3.2.2.1 Constructing a database

To conduct an MRA, it is first necessary to construct a dataset that comprises the results and methods of the existing literature. This would consist of different estimates of the impact of tax credits on R & D expenditures (beta), as well as a larger set of variables that describe the principal characteristics of the regression models that generated each of these estimates. The Appendix describes the search process by which the dataset used in this study is constructed; it also provides a summary of the data and a list of the studies that make up the dataset (see Table A1).

My basic approach was analogous to the approach used in medicine (a field in which MRA is widely employed) in that my study began by conducting a search of the main economic research database (EconLit) using relevant keywords. After examining the reference lists of these papers as well as some of the principal resources on R & D expenditures research, I assessed each paper to determine its suitability and proceeded to record key data if it satisfied the general form of equation 1. Simply, the rules for including the study in the meta-analysis are:

1. The study must present an empirical estimate of tax credits on R & D investment or sufficient information to calculate it.
2. The estimate must be based on a broad national database.
3. The estimate must also be derived from a regression analysis.

Therefore, my final dataset consists of data that records the characteristics of 124 "original regressions."

3.2.2.2 Defining a summary statistic

The dependent variable in a meta-regression analysis is usually a summary statistic, drawn from each study, while the independent variables stand for specific characteristics of empirical studies, like the method, design and data. Different studies may apply different summary measures and result different statistics, such as regression coefficient, elasticities, *t*-values and the results of other statistical tests.

The advantage of a summary statistic is to increase statistical power from many independent studies after its aggregation, so that this step is to identify specific characteristics among the studies and to code them. Then this summary statistic would address and integrate the direction and/or the size between tax credits and R & D activities in my study, so the meta-regression can explore the variation in either the sign or the magnitude of the effect across studies.

3.2.2.2.1 The significance effects and sign of tax credit measures

In my analysis, the strategy of comparing results across studies relies on identifying the relationship between tax credits and R & D investment, which is the main coefficient of the tax credit variable. If the tax credit reduces the user cost of R & D, the net present value of returns from the R & D are greater than zero. Then, the credit should result in higher levels of R & D investment than without the credit (holding other factors constant). To ascertain the validity of my main hypothesis, we are interested in determining whether the coefficient is significantly different from zero (i.e. a two-sided *t*-test).

First, the specifications are classified into three categories. These categories explore whether the coefficient is statistically significant at the 1%, 5%, and 10% level. To this end, this study utilises a set of dependent variables as dummy variables as summarised in Table 1.

Table 1 Dependent variables used in meta-regression analysis

Dependent variable	**Description**
Tax credits	=1, if the estimated coefficient is statistically significant at the 1% level and better
Tax credits	=1, if the estimated coefficient is statistically significant at the 5% level and better
Tax credits	=1, if the estimated coefficient is statistically significant at the 10% level and better

3.2.2.2.2 The size or magnitude of the effect

Then, meta-analysis establishes a quantitative format, called the effect size, which is one element of meta-analysis. Smith and Glass (1977) defines effect size as an empirical effect of an experimental literature, so it represents the critical quantitative information from each original model in the primary literature. Briefly, this step is to choose a parameter of interest.

The simple effect size estimate can be its mean and standard deviation in each study as a dependent variable in the meta-regression. However, there are other reported statistics to be used in the meta-analysis, such as the regression coefficients, elasticities, *t*-values, chi-square, *F*-distributions, and the results from the other statistical rests. McGaw and Glass (1980) and Glass et al. (1981) provide the form of the Pearson Product Moment Correlation as the effect size which is converted from various summary statistics for the degree of association between two variables. Cohen (1988, pp. 19-74) provides measures of effect size for *t*-tests between two group means.

Because the empirical studies mostly use different data sets, sample sizes and independent variables, variances of these estimated coefficients may not be equal and meta-regression errors are likely to be heteroscedastic. In order to compare with the research results from the empirical literature, it is necessary to transform the summary statistics to a common and comparable metric which is based on the concept of standardization (Lipsey & Wilson, 2001). Gene Glass (1976; 1977) introduced the concept of effect size to integrate the findings of an experimental literature, so that effect size allows diverse studies to be compared directly. In addition, Stanley and Jarrell (1989, pp. 161-170) pay attention to the reported *t*-statistics, which provide the critical tests in the empirical studies.[29]

Since several variables have been applied in the literature to test the relationship between tax credits and R & D investment, this study follows Stanley and Jarrell (1989) using *t*-values to compare a number of studies. In this study, the *t*-statistic which is considered as the dependent variable had to be an estimate of the impact of some measures of tax credit. Most of the studies provided more than one set of results for the estimation of initial regression. Following Stanley and Jarrell (1998), multiple estimates from the same study were used as separate observations if they referred to different years. Estimates from dissimilar models using data from

[29] Unlike effect size, a regression coefficient has its dimensionality, so that studies with different types of measurement could not be compared or combined. On the other hand, the reported *t-statistic* has no dimension and is a standardised measure of the parameter of interest from each study (Stanley & Jarrell, 1989, pp. 161-170).

the same year were also included as separate observations. Even estimates from similar models reported in separate publications by the same author using the same data were served as separate observation. On the other hand, an alternative modelling approach is to include only one estimate from each study and that is the best estimate by the authors. Nonetheless, the best estimate is not obvious in some cases, while the variation in the results is a key focus of some papers. This study therefore applies the first approach to aggregate different multiple estimates.

An advantage of the t-statistic is this standardized variable is a unit-less measure, allowing easy comparability across studies. Moreover, *t*-statistics represent the slope coefficient from the original regressions, which are simply the ratio of the estimated effects from the original regression (beta) divided by the standard error of the estimate (s). Then this study can ignore issues regarding the measurement scales of the R & D investment and tax credit variables. This allows me to include a range of measures of tax credits (such as user cost of R & D, B-index, tax credit rate, or a dummy of tax credit) and measures of R & D investment (like R & D intensity and R & D expenditure).

A disadvantage of *t*-statistics is that this study does not explain differences in the size of the estimated tax credit effects in the literature. But in defence of my approach, *t*-statistics are a function of size, and they are arguably more important in a scientific sense because they refer to statistical significance. Indeed, most econometric studies focus greater attention on significance than size.

To explain some variation in the empirical results, MRA in my study quantifies the impact of data and specification differences on the reported effect of tax credits on R & D activities. The dependent variable which is the parameter of interest contains a vector of estimates of the effect being measured. This study uses the estimates of *t*-statistics as measures of the effect of tax credits on R & D investment. It is clearly that *t*-statistics are explained by the methodological dummy variables, the continuous variables and the usual error term; these moderator variables are discussed below.

3.2.2.3 The choice of moderator variable

As observed above, a comparison of empirical studies is difficult due to the heterogeneity of the empirical models used. Before the meta-regression analysis is running, the third step in the MRA process is to choose the meta-independent variables, usually called moderator or predictor variables. In the econometric specification, those explanatory variables correspond to individual study characteristics that may have a substantial impact on the results of studies examining the relationship between tax credits and R & D activities. From my view, the sample across different literatures suggested a number of explanatory variables, so this study outlines a list of moderator variables before continuing the search and indicates the ways in which meta-regression analysis might provide evidence on them.

For example, this study depicts the key characteristics of each regression: the estimated impact of tax credits variable on R & D expenditures (beta); the standard error of beta (s) and its *t-statistic* (beta/s); the type of tax credit measure used to generate beta; the type of indicator used to measure R & D expenditure; the types of measures employed among the control variables; the sample size and structure of the data (e.g., panel, cross-section); and various properties of the sample (countries and time periods covered). Those moderator variables can be continuous variables or binary variables. The binary variables used in this study reflect the presence or absence of variables and generally take the form of dummy variables. However, not every study characteristics can be coded because of the insufficient information of data.

As a result, this step is to identify crucial characteristics of the studies and to code them. In my case, moderator variables consist of the dependent variable which refers to R & D expenditure or R & D intensity and the explanatory variable which is the measure of R & D tax credit, such as B-index, user cost of capital, or the dummy variable of tax credit. Furthermore, other explanatory variables which influence tax credits on R & D investment are also included in my meta-regression; these characteristics take the form of continuous and dummy variables. Next, it is going to represent eight types of interest in this study based on the codes generated from the studies and regressions within those studies in the sample.

3.2.2.3.1 Observations

Each observation is from a study analysing motivations for R & D expenditure. It is sensible to argue that the size of the sample can lead to different conclusions about the factors leading to R & D activities, so it is necessary to include the sample size into the meta-regression. In this case, observation is the sample size for each study estimate and it is a continuous variable. Besides, sample size varies significantly, ranging from 52 to 7138. To obtain more precise estimation, some studies that only represent the number of firms or industry are omitted in my study.

3.2.2.3.2 The time of data collection

Views of R & D expenditure change over time and one would think that these changing perspectives may affect the findings of studies examining the impact of tax credits on R & D expenditure. To capture any trend in tax credits, this analysis uses the average year of the data to control for any temporal impact on the effect estimate of tax credits on R & D expenditure. From cross-sectional analyses, the actual year of the data was coded. For estimates using panel data, the median year of the dependent variable used in the regression was also coded.

3.2.2.3.3 Measure of R & D expenditure

The following definitions have all been used to measure a firm's R & D expenditures, which are percentage of total employment consisting of scientists and engineers, percentage breakdown of R & D into basic and applied research, percentage of business unit sales, and R & D spending per $1000 sales. For instance, Farber (1981) considered that the share of scientists and engineers in the total workforce is one of the major determinants in R & D intensity. This is because scientists usually undertake R & D research, and also expand absorptive capacity, which better use the knowledge developed in other countries.

In this paper, two major types of R & D activities apply to measure the R & D activity of a firm, industry, state, or nation in most studies. Some studies used R & D intensity to capture the size R & D expenditure and others are considered R & D expenditure as the dependent variable in the sample. From the empirical studies, R & D intensity is defined as the ratio of expenditure to output or the ratio of expenditure to sales. Generally, different industries are expected to have different R & D expenditures due to the nature of products. If R & D is proportional to sales for nontax reasons, R & D intensity would provide more meaningful and appropriate information about the credit's effect than un-deflated R & D spending for cross-country analysis. Nonetheless, the level of R & D expenditure is difficult to measure accurately, because different classification or definition of R & D leads to various data among studies.

3.2.2.3.4 Measure of tax credits

The previous section indicates that firms seek to maximize profit by optimizing the pattern of input usage in the theoretical perspective. In practice, those empirical studies apply the basic model to the R & D tax credit issue.

Generally, tax credits have traditionally been measured using two types of measures. One is positive related to R & D expenditure and another is negative.

From the positive measure of tax credit, there are a range of methods identified in my study. First, some authors use a dichotomous variable to represent the R & D tax credit. It provides an indication of the total amount of change in R & D intensity following enactment of the tax credit. Therefore, the positive relationship is mainly represented by a dummy variable coded as 1 if the industry/country carries out a tax credit. Nonetheless, this is a rough approach, as it makes no allowance for differences in the level of credits between firms. Second, some econometric studies regressed R & D expenditure on a value of the tax credit. The actual value of the tax credit is an estimate of the tax credit received by each firm and gives an indication of the change in R & D intensity directly attributable to the tax credit. Nevertheless, this approach has the shortcomings of not being founded on a structural model and ignoring the stock aspect of knowledge associated with R & D. Third, some studies specify a demand equation for the R & D expenditures that depend on fiscal parameters through the user cost of capital. Higher credit rates leads to a larger percentage of R & D expenditures and reduce the cost of R & D activities. Fourth, one study had referred to the tax credit averaged across all projects, which the total credit is divided by the R & D expenditures. In this case the amount of R & D is positively related to the credit, averaged across all projects undertaken. As a result, the tax credit affects the cost of R & D activities through its effect on the price of conducting R & D.

On the other hand, if the estimate used was a measure of negative relationship, the sign of the *t*-statistic would be reversed. In my study, there are two major types of negative measures which are the user cost of R & D and B-index. The previous sector has concluded that R & D tax credit decreases the user cost of R & D. Hence, the low user cost or B-index stimulates R & D investment and there is a negative relationship between them.

3.2.2.3.5 Country

Different countries have promoted their technology policy with specific characteristics to stimulate the levels of industrial R & D, so there could be a publication bias of authors representing views accepted more or less in some countries. Despite the wide and increasing prevalence of tax credits, most academic studies have documented the effectiveness of tax credits in the US. Over time there was an increasing tendency to examine firms from elsewhere, such as Japan and Europe. To distinguish the studies with and without US data, the meta-regression analysis including US data was coded 1.

3.2.2.3.6 Analysis level of data

A body of existing studies evaluating the effect of R & D tax credits have conducted at the different levels of analysis, ranging from individual firm to the whole economy. The various analysis levels of data correspond to different estimations across studies. For instance, the range and type of industries may determine the differences in results, so some studies present more than one result.

In my case, I control the unit of analysis because tax credit and its effect on R & D expenditure may vary according to the unit that is analysis. Some empirical studies use firm- or industry-level data, and some studies have attempted to systematically evaluate the effectiveness of R & D tax credits across nations. Firm level data is common to apply both positive and negative tax credit measure estimating the effect on R & D investment. However, the macroeconomic approach generally allows the standard indicators to capture the effect, such as the B-index or user cost of the negative tax credit measure. Therefore, given the different sources of R & D expenditure, I distinguish between studies that examine R & D expenditures among a broad range of industries/countries and studies that address just one industry/country.

3.2.2.3.7 Data structure

The existing analyses contain various types of data, such as cross-section, time-series and panel data. First, dataset on a single phenomenon over multiple time periods is called time series, and firms or countries with different period of time are discussed. Second, dataset on multiple phenomena at a single point in time is called cross-sectional, so firms or countries with different level of tax credit can be compared. Third, dataset on multiple phenomena over multiple time periods is called panel data, and then there are controls for time-invariant differences among firms or countries.

Among different methodology of empirical studies, fixed effects and ordinary least-squares estimates often vary greatly as a result. To analyse the dynamic process and measure precise effects, the use of panel data have the advantage of reducing endogeneity and controlling the heterogeneity of the firms, sectors or countries that may be interesting and important. Therefore, the inclusion of the use of panel data allows detect whether it influences the effects of tax credits on R & D expenditures. In my analysis, regressions used a panel data method were coded 1, with other regressions coded 0.

3.2.2.3.8 Dummies

Among the empirical studies, the major determinants of R & D expenditure include not only the R & D tax credits but also other factors of R & D investment. Because the number of independent variables is widely varied, there is a high degree of heterogeneity with significant differences among those studies. For example, some omitted factors may influence both R & D expenditure and tax credit variables, such as the nature of competitive rivalry. To concern with endogeneity of R & D tax credit variable, most studies therefore have included dummy variables to capture those effects, such as time dummy and firm/industry dummy.

First, some studies include time variables to represent the effect of the omitted variables and control the effect that is common across time. Since various common shocks, like business cycle or technology shocks, would affect the ability of firms to perform R & D in the industrialised world, time dummy variable is applied into the model to get rid of annual macro economic shocks. In this case, time dummies capture the changes in R & D tax credits which authors were not able to incorporate into the measure of tax credit. Therefore, a full set of time dummy can capture technological progress or other time-specific effects which varies over time.

Additionally, R & D investment might be determined by a variety of firm- or industry-specific characteristics in the policy-making processes, such as the supply of scientists, language and culture, the degree of concentration as well as technological opportunities. It is also possible to observe some industrial pressure for R & D tax benefit, so the R & D companies and their lobbyists may attempt to practice the R & D tax policies in their favour. So long as these firm- or industry-specific characteristics are broadly stable over time, some authors captured these time-independent characteristics by the industry fixed effect and some considered them as firm or industry dummies among the empirical studies.

3.2.2.4 Sample construction

This section briefly summarises the steps of meta-regression analysis which contain the summary statistics, in this case *t*-statistics serving as the dependent variable, and the independent variables, called moderator variables. Moderator variables are the main characteristics of the empirical studies used in the MRA and are coded as dummy and continuous variables. Therefore, the *t*-statistics are explained by the dummy variables, continuous variables, and the usual error term.

Before statistical analyses are conducted, this study investigated a number of potential moderator variables representing different econometric specification and includes data on the following four categories of study characteristics: choice of R & D investment measure, measures of R & D tax credit, choice of other explanatory variables in the original regression, and type of data used for the country that generated the observation. These are summarised below in Table 2.

First, the R & D investment measure among a range of studies consists of R & D intensity and R & D expenditure. Each of the dependent variables in the empirical studies serves as a control variable in the meta-regression model. Second, R & D tax credit characteristics include a dummy variable of tax credit, B-index, and user cost of R & D. Third, different studies have considered a range of explanatory variables affecting the effects of tax credits on R & D investment. Fourth, study data characteristics respectively capture whether the tax credit estimates was obtained using panel, industry/firm-level or country-level data, the observation of data, the average year of the data, and a country dummy indicating whether the study was of an the American economy or not.

The meta-independent variables summarised in Table 2 consist of the 26 study characteristics used in this study based on the codes generated from the original studies and regressions within the sample. The final MRA data consist of 124 regression results and characteristics from 21 studies of R & D tax credits.

Table 2 Meta-regression variable characteristics

Variable	Definition
R & D investment measures and variable characteristics	
RDexp	=1, R & D investment measure is R & D expenditure
RDint	=1, R & D investment measure is R & D intensity
Tax credit measures and variable characteristics	
dumvar	=1, tax credit measure is dummy variable
bindex	=1, tax credit measure is B-index
usercost	=1, tax credit measure is user cost
Study explanatory variables	
Size	=1, includes sales or output as explanatory variable
human	=1, includes human capital indicator as explanatory variable
GDP	=1, includes GDP or GNP as explanatory variable
leverage	=1, includes leverage indicator as explanatory variable
cashflow	=1, includes cash flow as explanatory variable
Q	=1, includes Tobin's Q as explanatory variable
patent	=1, includes patent indicator as explanatory variable
subsidy	=1, includes subsidy as explanatory variable
tax	=1, includes other tax indicator as explanatory variable
inflation	=1, includes inflation indicator as explanatory variable
public	=1, includes public sector R & D as explanatory variable
intRD	=1, includes R & D intensity as explanatory variable
intcap	=1, includes capital intensity as explanatory variable
laggeddep	=1, includes lagged dependent variable as explanatory variable
tdum	=1, includes time dummy as explanatory variable
Data characteristics	
obs	The observation of data
year	The average year of data
us	=1, if the US is included in the data
indfir	=1, observation uses industry/firm level data
coun	=1, observation uses country level data
panel	=1, observation uses panel data

An overview of how choice of R & D investment and tax credit measures determine the findings of significant effects is presented in Table 3. These summary results suggest that the use of R & D intensity as the dependent variable is associated with more statistically significant findings of R & D tax credit effects than is R & D expenditure measure. Second, with respect to the choice of R & D tax credit measure, B-index, on average, produces more statistically significant results than when it is estimated as a dummy variable or user cost. Third, comparing the positive measures with the negative measures of tax credit, it is interesting to note that negative measures of R & D tax credit results are, on average, more statistically significant than the positive results. While there is a positive *t*-statistic in the positive measure of R & D tax credits in Table 3, as discussed in the previous section there are a variety of different forms included in this measure. This is interpreted as revealing the predominance of complementarity between tax credits and R & D activities, so R & D tax credits can stimulate R & D investment. On the flip-side, the negative *t*-statistic in the negative measure of R & D tax credit indicates that R & D tax credits typically lower the user cost, so the level of R & D investment increases.

Table 3 Composite sample statistics

	Number of estimates contributing to statistic	**Average distributed statistics**
Dependent variable		
R & D intensity	67	-2.45489
R & D expenditure	52	0.945054
others	5	-2.1993
R & D tax credit measure		
Dummy variable	24	1.731157
B-index	49	-3.92246
User cost	28	-0.703301
Others	23	1.91364
Sign measure of R & D tax credit		
Positive	42	2.133285
Negative	82	-2.63328

3.2.2.5 Empirical methodology

As observed above, the main hypothesis is straightforward: if the tax credit reduces the cost of R & D activity, the R & D tax credit should induce higher levels of R & D activity than without the credit. Equation 3 below provides a general way of testing for study characteristics in my meta-regression model:

$$T_2 = \beta_0 + \beta_1 * MV_1 + \beta_2 * MV_2 + \beta_3 * MV_3 + \beta_4 * MV_4 + \varepsilon \quad (3)$$

Where: T_2 is the effect of tax credits on R & D investment reported in the original studies, MV_1 represents the R & D investment measure, MV_2 represents the R & D tax credit measures, MV_3 represents data characteristics and MV_4 represents the various explanatory variables reported in the original studies.

To ascertain the validity of my hypothesis, the first step is to examine whether the coefficient is significantly different from zero, so that my first estimation relates study which attributes to the likelihood of the significant estimated R & D tax credit effects. There are three categories in this specification as the previous section showed. The dependent variable takes on the value of 1 if the estimated coefficient is statistically significant at the 1%, 5%, and 10% level as well as 0 otherwise. For example, 59 study results have tax credit coefficients that are statistically significant at the 1% level and 65 have coefficient that are insignificant at that level.

With the data organised, this study now explores what study characteristics explain the magnitude of the estimated tax credit effects by estimating a multivariate regression as expressed by Equation 3. The dependent variable here is the *t*-value of the estimated tax credit impact on R & D activity, so that MRA can explain the variation in the *t*-statistic estimate from the existing literature. To get a better understanding of how different types of tax credit measure impacted R & D activity across studies, this study separates the positive as well as negative measures of tax credit first and then combines all measures from empirical studies.

Thus, these diverse applications of meta-regression models across a broad selection of publication and varied statistical power are summarised, so the results of the MRA can be used to provide a plausible and objective interpretation of this area of economic research.

4 Empirical Results and Discussion

Six specifications designed to inform what study attributes affect the significance, sign, and magnitude of the estimated R & D tax credit effects are estimated and the results are reported below. Positive coefficients of the moderator variables indicate that the characteristic of the study tends to provide a significant relationship between R & D tax credits and R & D expenditures. A negative sign implies that the associated characteristic of the study tends to return a non-significant relationship between the two variables. A non-significant coefficient implies that the characteristic of the study does not influence the relationship.

4.1 Significance and sign of estimates tax credit effects

Consistent with the empirical methodology introduced in the previous section, model 1 in Table 4 presents *t*-statistics of the association of various study and data characteristics with the likelihood of a study finding tax credits that are statistically significant at the 1% level or better. From the results, both choices of the study-dependent variable, R & D intensity and R & D expenditure, do not significantly affect the likelihood of tax credit significance. On the other hand, the use of B-index as a measure of tax credits significantly increases the likelihood of finding significant tax credit effect. Among the variables capturing data characteristics, the coefficient of the observation, the country of data, and the panel data are also significant.

First, it is reasonable to expect that if tax credit is significant across studies, estimation of equation 2 will generate a positive and statistically significant coefficient for the observation of data. In model 1 (Table 4), results show that this expectation obtains and suggest that tax credit is strongly significant in the studies taken cumulatively. Intuitively, larger datasets may more precisely measure of the effects of the determinants of R & D investment, and so additional observations increase the likelihood of obtaining a statistically significant tax credit *t*-statistics. Second, I note that estimated coefficient of US is significant and positive in magnitude. It means that US has a greater likelihood of finding positive *t*-statistics, so that studies concerning country in US appear to be significantly higher relative to other countries. Third, the use of panel data also appears to significantly affect the likelihood of tax credit findings.

Since the economic theory indicates that user cost of capital is a contributor to R & D investment, the exclusion of variables which are related to the user cost in a study may affect the estimated tax credit effects leading to a mis-specified model. This is a matter of omitted variable bias. Specifically, tax credit effects obtained from regressions that include an indicator of size, human capital, Tobin's Q, and subsidy, and therefore hold it constant in the estimation, are likely to generate more statistically significant tax credit effects.

Both model 2 and 3 (in Table 4) present sensitivity results at two additional levels of significance for the estimated tax credit effects. Model 2 shows results for likelihood of significance at the 5% level or better, while model 3 repeats the analysis for the case of significance at the 10% level or better. Comparing three different models, the values and statistical significance of estimated *t*-statistics are quite similar in model 2 and 3. Only a few variables are statistically significant at the 1% level in explaining the likelihood of a tax credit result being effective. This is partially explained by the fact that 17 more observations are significant at the 10% level or greater as opposed to at the 5% level or greater, while 25 observations that are significant at the 5% level are not significant at the 1% level.

Accordingly, in model 1, the statistically significant coefficient of observation, B-index of tax credit measure, Tobin's Q, and the panel data are in accordant with model 2 and 3. Furthermore, the *t*-statistic signs are also consistent with those variables of modle 2 and 3. This suggests that the likelihood of tax credit being both positive and significant increases in samples with a greater number of observations. Also, the coefficients of B-index, Tobin's Q, and panel data which are significant indicate that the inclusion Tobin's Q and the application of B-index as well as panel data generate more statistically significant findings of *t*-statistics from R & D tax credits.

As observed above, there are some similarities between model 2 and model 3. For instance, in a set of data characteristics, the estimated *t*-statistics of industry/firm-level data or the panel data are significantly negative. It indicates that the industry/firm-level data or the panel data appears to generate less statistically significant findings of tax credits on R & D investment. Besides, the inclusion of cash flow is also associated with less significant tax credit effects. On the contrary, the B-index or user cost of R & D tax credit measure significantly increases the likelihood of finding significant tax credit effects. In addition, a range of study explanatory variables are the significantly higher likelihood of finding significant tax credit effects, like the inclusion of leverage, and Tobin's Q.

In the three specifications discussed so far, the positive and negative measures of tax credit are estimated together, so the results cannot be clearly to represent a complementarity or substitutability between *t*-statistics and moderator variables. In the following table, I separate the positive and negative measures of R & D tax credits to examine whether the relationship between R & D tax credits and R & D investment influences by any moderator variables.

Table 4 Multivariate regression – Statistically significant at the 1%, 5% and 10% level or better

	model 1 (1%)		model 2 5%		model 3 10%	
	coef.	t	coef.	t	coef.	t
cons	-131.0542	-1.45	-38.41403	-0.42	-93.85927	-1.36
obs	0.0002828	3.01 ***	0.0002742	2.91 ***	0.0002115	2.94 ***
year	0.0659958	1.46	0.0207685	0.46	0.0480877	1.39
us	0.3843209	1.69 *	-0.1191389	-0.52	0.0175528	0.1
indfir	-0.8750346	-1.1	-2.366127	-2.98 ***	-1.83877	-3.04 ***
coun	0.1748021	0.33	-0.0587208	-0.11	0.1825068	0.46
panel	-1.330235	-2.14 **	-2.409501	-3.87 ***	-2.14556	-4.51 ***
RDint	-0.6519327	-1.06	-1.470152	-2.39 **	-0.9104382	-1.94 *
RDexp	-0.6707524	-1.58	-0.802836	-1.88 *	-0.3755488	-1.15
dumvar	-0.0656835	-0.09	0.5707828	0.79	0.7513367	1.37
bindex	1.324658	2.32 **	1.535257	2.68 ***	1.741965	3.99 ***
usercost	0.9409537	1.33	1.585877	2.24 **	1.849354	3.43 ***
size	0.3816372	1.78 *	0.1400939	0.65	0.0980172	0.6
human	1.349243	2.42 **	0.4838898	0.87	0.4304971	1.01
GDP	-0.1750782	-1.00	-0.1388474	-0.8	0.0643641	0.48
leverage	0.398006	0.22	3.473469	1.94 *	2.948602	2.16 **
cashflow	-0.6229534	-0.41	-3.126615	-2.05 **	-2.855857	-2.45 **
Q	1.924777	1.87 *	2.590625	2.51 **	2.811465	3.57 ***
patent	0.1759948	0.40	-0.9278188	-2.08 **	-0.0784516	-0.23
subsidy	0.2732423	1.75 *	0.0464554	0.3	0.1584906	1.33
tax	-0.2600681	-0.51	-0.4078035	-0.81	-0.2272165	-0.59
inflation	-0.6659457	-2.02 **	-0.4009129	-1.22	-0.4967248	-1.97 **
public	-0.1859506	-1.3	-0.0948221	-0.66	-0.0685741	-0.63
intRD	-0.3080616	-0.26	0.7963194	0.67	0.6363424	0.7
intcap	0.2435776	0.18	-2.103041	-1.55	-1.921849	-1.85 *
laggeddep	0.216718	1.72 *	0.2254316	1.78 *	0.0754848	0.78
tdum	0.4226875	2.68 ***	0.3225583	2.04 **	0.0957856	0.8
n	124		124		124	
R-square	0.551		0.486		0.5672	
F-statistic	4.578115		3.52694		4.889008	

4.2 Determinants of the magnitude of *t*-statistics

The *t*-statistic variable is then regressed on several study characteristics that are presumed to influence the study outcome. The previous section detailed that this study classifies the data into three groups based upon the measure of tax credit in order to validate my hypothesis. The first measure includes only the study observations with a positive measure of tax credit, the second one includes those with a negative measure of tax credit, and the third one includes all measures of tax credit. Furthermore, there are three types of specification in each measure of tax credits. Hence, the following tables report multivariate regression results of the MRA model and the dependent variable in three measures is all the *t*-statistics for tax credit impact on R & D investment.

4.2.1 The positive measure of R & D tax credits

The main variable of interest in this study is the intercept term estimated by the resulting MRA models (β_0), for it will give us an estimate of the summary tax credit impact on R & D activity. That is, the *t*-statistics when differences across studies are removed. Basically, the financial advantage given to the firm, like an increase in tax credit rate, might increase the rate of return, so the firms might extend the R & D activity. In model 1 reported in Table 5, there are only including data characteristics as moderator variables. The intercept in model 1 is significantly positive, implying that there is a statistically significant relationship between tax credit and R & D activity. After adding study explanatory variables (model 2) and variable characteristics of R & D investment measure as well as tax credit (model 3), the intercept term was dropped.

In addition, the MRA assists in identifying the importance of moderating variables on t-statistics. In model 1, some data characteristics do affect the empirical analysis of the influence of tax credits on R & D activities, such as observation, year and industry/firm level of data. The significantly positive relationship indicates that industry/firm level of data tends to return a significant relationship between tax credits and R & D activity. In contrast, a negative coefficient implies that observation and the average year of data tends to provide a non-significant relationship between the two.

In model 2 and 3, there is existing non-significant coefficient among all the moderator variables, implying that characteristics of the study do not influence the relationship if the study considers many characteristic of the study. Then, the method of MRA cannot analyse the differences between study findings. In addition, there are some moderator variables dropped from the result of MRA due to the collinearity of data. For instance, a coefficient for R & D expenditure could not be estimated using positive measure of R & D tax credit because of collinearity, as 39 of 42 observations in this subsample use R & D expenditure as the dependent variable.

Table 5 Multivariate regression – positive measure of R & D tax credit

	model 1			model 2		model 3	
	Coef.	t		Coef.	t	Coef.	t
constant	288.9767	2.31	**	(dropped)		(dropped)	
obs	-0.0004663	-2.52	**	-0.0187142	-0.36	-0.0187142	-0.36
year	-0.1452273	-2.31	**	-0.0229717	-0.37	0.0207892	0.36
us	1.017812	1.41		1.056923	1.31	1.056923	1.31
indfir	2.634847	3.7	***	95.76878	0.37	(dropped)	
coun	-0.0782307	-0.07		(dropped)		(dropped)	
panel	0.4394993	0.93		(dropped)		(dropped)	
RDint						-25.11444	-0.36
RDexp						(dropped)	
dum						-12.83144	-0.33
bindex						(dropped)	
usercost						(dropped)	
size				0.0409192	0.05	0.0409192	0.05
human				(dropped)		-129.7224	-0.36
GDP				51.44129	0.37	93.90452	0.36
leverage				(dropped)		(dropped)	
cashflow				(dropped)		(dropped)	
Q				-29.88779	-0.34	-21.44386	-0.33
patent				(dropped)		(dropped)	
subsidy				-34.30375	-0.34	(dropped)	
tax				31.29581	0.35	10.12983	0.35
inflation				(dropped)		(dropped)	
public				(dropped)		(dropped)	
intRD				31.03623	0.35	5.878033	0.32
intcap				-46.45546	-0.35	(dropped)	
lagdep				-0.1430768	-0.18	-0.1430768	-0.18
timedum				-33.89127	-0.35	-12.65965	-0.35
n	42			42		42	
R-square	0.4254			0.4604		0.4606	
F-statistic	4.319353			10.60263		10.60263	

*coefficient statistically significantly at the 0.1 level

**coefficient statistically significantly at the 0.05 level

***coefficient statistically significantly at the 0.01 level

4.2.2 The negative measure of R & D tax credit

Table 6 shows the result of the results of the meta-regression estimates in the negative measure of R & D tax credits. The intercept term in model 1 is statistically significant, implying that an increase in the user cost reduce R & D activity with the negative measure of R & D tax credits. Similar to the positive measure of R & D tax credits, the intercept terms in model 2 and 3 are also dropped.

Considering a range of moderator variables, the variables for observation, the inclusion of US, industry/firm level data, country level data and panel data in model 1 play no role in explaining differences across the studies. On the other hand, the variable of the average year of data is significantly positive, implying that early studies seem to give weaker support for the relationship between tax credits and R & D activity under the studies with the negative measure of tax credit.

In contrast with the positive measure, the results of negative measure of tax credit in model 2 and 3 represent few significant coefficients. For instance, the variables for the inclusion of leverage indicator, subsidy, lagged dependent variable and time dummy are significantly negative in model 2. However, the study that includes inflation indicator as explanatory variable find a more significant relationship between tax credits and R & D expenditure under the negative measure of R & D tax credit.

In addition, the coefficient of observation in model 3 is significantly negative and indicates substitutability between observation and the effect of R & D tax credits on R & D expenditure. That is larger number of observations decrease the likelihood of tax credits effect on R & D investment, so there is no statistical support for an empirical effect of tax credits on R & D. Also, the significantly negative results appear in the studies with the time dummy variables and then the studies with time dummy variables tend to weaken the relationship between tax credits and R & D activity. Second, a significantly positive coefficient of the size of inflation implies complementarity between two variables, so that studies including the size or inflation indicators increase the effect of tax credits on R & D expenditure. Third, a non-significant coefficient means that moderator variables do not stimulate the effect of R & D tax credits on R & D expenditure, but neither do they impede the effect.

Consequently, results for inclusion of various independent variables show highly significant coefficients in the subsample of negative measure of tax credit, but insignificant in the subsample of positive measure. For the negative subsample, the signs of the estimated coefficients are almost consistent with those of Table 4; that is, the observation of data, or inclusion of size, inflation, or time dummy in the R & D investment model is associated with the likelihood of a statistically significant result. However, the direction of the coefficient might be different due to the different measures of R & D tax credits.

Table 6 Multivariate regression – negative measure of R & D tax credit

	model 1		model 2		model 3	
	Coef.	t	Coef.	t	Coef.	t
constant	-1090.608	-3.61 ***	(dropped)		(dropped)	
obs	0.0005015	1.13	-0.000161	-0.59	-0.0006873	-2.01 **
year	0.5461151	3.6 ***	0.0472573	0.34	0.160474	1
us	-0.923668	-0.39	-46.56398	-0.34	-164.3275	-1.02
indfir	(dropped)		-46.45303	-0.33	-162.1021	-1
coun	5.465797	1.5	(dropped)		(dropped)	
panel	-3.785368	-1.45	-49.09016	-0.35	-160.6582	-1
RDint					3.925443	2 **
RDexp					3.729185	2.33 **
dum					-167.8323	-1.05
bindex					(dropped)	
usercost					-2.515878	-1.37
size			0.531216	0.68	3.557769	1.67 *
human			-51.37733	-0.37	(dropped)	
GDP			0.4838237	0.83	0.3037912	0.53
leverage			-4.278121	-3.47 ***	(dropped)	
cashflow			(dropped)		(dropped)	
Q			(dropped)		(dropped)	
patent			0.1746573	0.16	1.026486	0.7
subsidy			-1.107011	-2.24 **	-0.8483584	-1.6
tax			(dropped)		(dropped)	
inflation			5.182812	5.08 ***	4.87823	4.55 ***
public			-0.1715077	-0.37	-0.4117196	-0.9
intRD			(dropped)		(dropped)	
intcap			(dropped)		(dropped)	
lagdep			-1.099785	-2.4 **	-0.7586734	-1.58
timedum			-1.359372	-2.73 ***	-1.591427	-3.08 ***
n	82		82		82	
R-square	0.1846		0.8227		0.8373	
F-statistic	3.440345		45.33725		42.63288	

*coefficient statistically significantly at the 0.1 level

**coefficient statistically significantly at the 0.05 level

***coefficient statistically significantly at the 0.01 level

4.2.3 Both positive and negative measures of R & D tax credit

Table 7 presents an estimate of the MRA model including both positive and negative measure of tax credit. Notably, the intercept term from equation 3 is negative across all three specifications, implying that there is a decrease in R & D activity from R & D tax credits; especially in model 2 where the intercept term is statistically significant.

The first sets of controls shown in model 1 are what we term the variables of data characteristics. The coefficients on the variable “us” and “coun” is significantly positive and negative at the 1% level, respectively. Model 2 then introduces 15 study explanatory variables as moderator variables.

Finally, variable characteristics in R & D investment and tax credits measures are also considered as moderator variables. In model 3, no significant impact is recorded among the variables of data characteristics. In the study explanatory variables, those studies including tax indicator, inflation indicator, or capital intensity as explanatory variables tended to strengthen the relationship between tax credits and R & D activities. However, the statistically negative coefficients; such as the human capital indicator, leverage indicator, subsidy and time dummy variables indicate that the inclusion of those variables weaken the relationship.

Table 7 Multivariate regression – all observations (combined)

	model 1		model 2		model 3	
	Coef.	t	Coef.	t	Coef.	t
constant	-111.828	-0.62	-374.9957	-1.87 *	-144.7549	-0.49
obs	-0.000372	-1.41	0.0000729	0.28	-0.0004955	-1.62
year	0.055413	0.62	0.1903869	1.89 *	0.0726	0.5
us	2.287507	2.85 ***	1.338147	1.67 *	1.211614	1.64
indfir	0.8990885	0.66	-3.319283	-1.45	1.861495	0.72
coun	-3.970187	-3.84 ***	-3.635143	-3 ***	-2.19597	-1.29
panel	0.6814245	0.8	-3.298199	-2.5 **	2.501353	1.24
RDint					3.953239	1.98 *
RDexp					3.004934	2.17 **
dum					-1.529734	-0.65
bindex					-6.870985	-3.7 ***
usercost					-5.672459	-2.47 **
size			-0.3353596	-0.63	-0.2838061	-0.41
human			-2.864304	-2.4 **	-5.931173	-3.27 ***
GDP			0.9834093	1.7 *	0.5143084	0.91
leverage			-3.509255	-1.79 *	-14.20978	-2.44 **
cashflow			-1.270804	-0.73	6.774339	1.37
Q			5.753436	2.98 ***	0.9796328	0.29
patent			0.9384491	0.86	1.451953	1
subsidy			-1.542527	-3.27 ***	-1.07934	-2.12 **
tax			4.496509	4.48 ***	3.886049	2.37 **
inflation			4.476533	4.62 ***	4.775505	4.46 ***
public			-0.4807784	-1.01	-0.3500996	-0.76
intRD			-1.379385	-1.32	-5.601818	-1.46
intcap			2.772105	1.41	10.88499	2.46 **
lagdep			-0.9057511	-2.42 **	-0.5504706	-1.34
timedum			-0.6748324	-1.74 *	-1.756603	-3.43 ***
n	124		124		124	
R-square	0.3931		0.8601		0.8875	
F-statistic	12.6283		29.85426		29.44174	

*coefficient statistically significantly at the 0.1 level

**coefficient statistically significantly at the 0.05 level

***coefficient statistically significantly at the 0.01 level

4.2.4 Summary

The estimated coefficients reflect the relationship in terms of the degree of the tax credits effect on R & D investment; as such, these specifications will likely generate significant or non-significant results for moderator variables instead of affecting the direction of *t*-statistics.

First, as regards R & D investment measurement, reported in Tables 6 and 7, the estimated coefficient of R & D intensity and R & D expenditure are significant and positive. The studies which consider R & D intensity and R & D expenditure as the dependent variable report higher *t*-ratios.

Second, among R & D tax credits measures, the dummy variable measure does not significantly affect the magnitude of *t*-statistics in the specification where all observations are included (combined). Furthermore, B-index and user cost measures are not significant in the positive and negative measures, but in the combined specification B-index and user cost are significant and negative.

Third, while the estimated coefficients of study explanatory variables are all insignificant in Table 5, the striking result in Tables 6 and 7 is that inflation and time dummy are robustly statistically significant, at the 1% level. It implies that across all studies, the inflation variable and time dummy are statistically significantly correlated with R & D activity. The inflation variable has a significantly positive sign, implying the studies that include inflation variable have higher *t*-ratio. On the other hand, this could be due to the fact that a statistically significant negative sign from the time dummy indicates the studies with time dummy have lower *t*-ratio. Further Table 7 indicates that there are other variables are statistically significant, such as human capital, leverage, subsidy, capital intensity, and other tax policy.

Fourth, among data characteristics, some variables are significant in model 1, implying those characteristics systematically influence the *t*-ratio values. After including other moderator variables in model 3, the data characteristic variables generally become less or even insignificant. This means those moderator variables have no impact on the relationship between tax credits and R & D activity.

Therefore, as the number of moderator variables increase, the R-square among three tables also increase. The high R-square indicates that more moderator variables can explain the variation among these *t*-value estimates. For instance, the R-square of model 3, reported in Table 7, is up to 88.75% which means that this model is better to explain more than 88.75 percent of the variation among these estimates of tax credits.

5 Concluding Remarks

Estimating the economic value of R & D tax credits presents an important and growing field of applied research. Valuation of R & D tax credit policy offers a way for decision-makers to compare the (intangible) benefits (and costs) of various alternatives. Armed with valuation estimates, policymakers can see the benefits of undertaking certain projects and analysts can undertake more complete cost-benefit analyses.

This study presents a quantitative review of the empirical literature on R & D investment from R & D tax credit policy. The research has painted a broad picture of the sorts of applications, methods, and findings, in the published literature as well as varies widely within each of these dimensions. This study applies meta-regression analysis with a sample of 124 *t*-statistics assembled from 21 studies to investigate the overall impact of tax credits across a wide range of studies, so that this study can examine which study characteristics explain the significance, sign (direction), and magnitude of the documented *t*-statistics findings. In this final section I revisit my initial hypotheses and summarise my findings. I conclude with a discussion of the theoretical and methodological implications of these findings.

Finding 1: My results show *patents* do not influence the estimated effect of tax credits on R & D investment.

Finding 2: The partial association between tax credits and R & D spending will be more negative when the regression controls for *human capital*.

Finding 3: The partial association between tax credits and R & D expenditure will be more negative when the regression controls for *subsidy policy*.

Finding 4: *Other tax policy* increases the estimated effect of tax credits on R & D expenditure.

Finding 5: The partial association between tax credits and R & D expenditure will be more positive when the regression controls for *inflation*. In the meta-regressions for negative and all measures of R & D tax credit there is an increase in tax credit coefficients or *t*-statistics after controlling for inflation. Hence, inflation strengthens the relationship between tax credits and R & D activity across the sample of studies.

Finding 6: *Tobin's Q* and *cash flow* do not appear to impact on the estimated effect of R & D tax credits on R & D activities.

Finding 7: Controlling for *leverage* tends to reduce the effect of tax credits on R & D spending.

Finding 8: *Lagged R & D* does not appear to impact on the estimated effect of R & D tax credits on R & D spending.

Finding 9: My results indicate the inclusion of *time* as a variable does matter. Controlling for time through a dummy variable contributes to a modest decrease in the *t*-statistics associated with negative and all measures of tax credit as the variable does not influence the estimated effect in the positive measure. Therefore, the time dummy variable reduces the strength of the relationship between tax credits and R & D activity among the sample of studies.

While economists’ investigations of R & D tax credit issues have become increasingly complex in the new growth empirics literature; a meta-regression analysis of this literature explains many of the specific sources of variation in key findings. To revisit my main hypothesis, the likelihood that a particular relationship is found to be significant is quite sensitive to the characteristics of the study. As meta-regression only includes data characteristics as moderator variables, the intercept term is statistically significant among positive and negative measures of tax credit. However, if the regression includes other study characteristics, the intercept term is dropped in the positive and negative measure of R & D tax credits.

In addition, this study indicates that positive measures of R & D tax credits are the main drag on R & D expenditure, while the effects of negative measure of R & D tax credits are more varied and dependent upon such other factors as economic and social determinants, especially with regard to size, inflation and macro economic shocks. These explanations have implications for policy makers and researchers. First, inflation appears to be another conditioning factor linking tax credits to R & D expenditure, but links between inflation and tax credits have received little attention. Second, inclusion of time as a dummy variable represents common shocks, such as the business cycle or technological innovation, is recommended. Researchers should explore the complex means by which tax credits influences R & D expenditure by the macro economic shocks. Finally, the considerable extent to which methodological choices explain variations in this literature must have an important bearing on future macroeconomic research into linkages between tax credits and R & D investment. Researchers should give careful thought to the scope of their data, the choice of estimation technique and especially, the selection of control variables. The implication of this result is that policy makers and researchers need to pay close attention to the extent to which their results are sensitive to alternative assumptions and techniques.

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Appendix: Construction of the dataset

To conduct an MRA, a dataset would consist of different estimates of the impact of tax credits on R & D expenditures and a set of variables that describe the specific characteristics of the regression models. From my research, many empirical studies have examined indirect measures influencing R & D activities and have explained variations among studies. The search process by which I derive this dataset is described below.

The first stage of my meta-analysis is to include all studies, published or not. The studies were drawn from the economic research database (Econlit), based on a search of any relevant keywords, such as tax credit, tax incentive, fiscal incentive in all field. Furthermore, each relevant paper found was then checked for references to other studies that might have been missed by the search or not included. These additional papers were then obtained from the journals or via web search engines.

Second, after reviewing articles published in academic journals or in related Working Paper Series, I found most empirical studies discussed the elasticity of R & D tax credits and many studies in my database employ US data. To fit into the meta-regression analysis, the sample used here includes all studies that use multivariate regression techniques to examine not only the relationship between tax credits and R & D expenditures, but also the relationship between R & D expenditures and other determinants. Therefore, those empirical studies relate the private R & D expenditures to R & D tax credits and some control variables that influence R & D. Formally the empirical studies estimate the following relationship:

R & D expenditures = f (R & D tax credit, other variables)

The dependent variable refers to R & D expenditure or R & D intensity, so I excluded any studies where some measures of R & D expenditures were not the dependent variable. Furthermore, the key explanatory variable is tax credits. However, the dataset included the studies which not only simply focused on the impact of tax credit on R &

D expenditures but also examined the relationship between other variables and R & D expenditure. Because of the wide variety of tax credit measures among studies, dummies were included to denote these different types of measures, such as user cost of R & D and B-index.

Third, I only included studies that supplied sufficient information on the direction and magnitude of the effect of tax incentives on R & D expenditures as well as the corresponding standard error and *t*-statistic, even though a lack of data on R & D tax credits has limited the research exploring the effect of the tax credit on R & D activity.

Fifth, there is one result that appear to be a significant outlier, so I eliminated this observation, namely one of results reported by Koga (2003) from my sample because it has what appears to be excessively low *t*-statistics compared to the other studies.

After all, the aim of meta-regression analysis is to obtain estimates of how research choices influence the results. All 21 empirical studies of R & D tax credits, comprising 124 estimates are included in this study. Table A1 provides a summary of the data and a list of the studies that make up the dataset in the table.

Table A1: Studies used in the meta-analysis

Author (Year)	Observations	Type of tax incentives	*t*-value
Baghana and Mohnen (2009)	1386	user cost	-0.647058824
	1386	user cost	-2.971428571
	264	user cost	-1.348837209
	1122	user cost	-3.227272727
Berger (1993)	3551	dummy variable	3.999
	3551	dummy variable	2.795
Billings and Fried (1999)	113	dummy variable	2.45
Billings, Glazunov and Houston (2001)	1848	user cost	-2.837
	1848	dummy variable	0.741
	1848	user cost	-2.729
	1848	dummy variable	1.329

Bloom, Griffith and Van Reenen (2002)	165	user cost	-3.504950495
	156	user cost	-4.339130435
	155	user cost	-2.666666667
	155	user cost	-2.066666667
	164	user cost	-2.423728814
Falk (2006)	99	B-index	-2.79
	93	B-index	-1.83
	72	B-index	-4.11
	99	B-index	-1.98
	99	B-index	-1.86
	99	B-index	-1.87
	99	B-index	-1.86
	99	B-index	-1.68
	99	B-index	-1.79
	99	B-index	-2.37
	93	B-index	-1.89
	93	B-index	-1.67
	93	B-index	-1.58
	92	B-index	-1.76
	92	B-index	-1.8
	73	B-index	-2.97
	73	B-index	-4.16
	73	B-index	-2.81
	73	B-index	-2.84
	73	B-index	-3.1
Guellec and Potterie (1997)	216	B-index	-5.25
	216	B-index	-5.33
	216	B-index	-4.87
	216	B-index	-4.12
	216	B-index	-4.067
	216	B-index	-4.37
	216	B-index	-6.317
	216	B-index	-5.26
	216	B-index	-5.14
	216	B-index	-5.45
	216	B-index	-5.43
Guellec and Potterie (2001)	216	B-index	-5.42
	216	B-index	-5.75

	216	B-index	-5.12
	216	B-index	-3.76
	216	B-index	-4.26
	216	B-index	-5.94
Guellec and Potterie (2003)	199	B-index	-7.34
	199	B-index	-7.49
	199	B-index	-6.35
	199	B-index	-4.09
	199	B-index	-6
	199	B-index	-7.18
	199	B-index	-6.06
	199	B-index	-7.56
Jaumotte and Pain (2005)	380	user cost	4.9
	380	user cost	0.4
	380	user cost	2.5
	380	user cost	2.7
	380	user cost	2
	380	user cost	1.9
	380	user cost	2.2
	380	user cost	2.4
	380	user cost	2
	380	user cost	2.1
	380	user cost	0.4
Klassen, Pittman and Reed (2004)	821	R & D credit, averaged over all projects	4.85
	821	credit rate	3.92
	821	R & D credit, averaged over all projects	1.97
	821	R & D credit, averaged over all projects	1.86
	821	credit rate	2.58
	821	credit rate	-1.12
	821	R & D credit, averaged over all projects	1.48
	821	R & D credit,	6.49

		averaged over all projects	
	821	credit rate	2.31
	821	credit rate	0.46
	821	R & D credit, averaged over all projects	4.34
	821	credit rate	3.08
	821	R & D credit, averaged over all projects	4.23
	821	credit rate	2.88
Koga (2003)	*5738*	*user cost*	*-3.282409639*
	2633	*user cost*	*-0.337787887*
	6098	*user cost*	*-3.223552894*
	2633	*user cost*	*-0.589082021*
	3345	*user cost*	*-4.195885126*
	1185	*user cost*	*-2.801980198*
MacDonald (2003)	170	credit rate	-0.11
	170	credit rate	-0.11
	170	credit rate	-0.1
Paff (2004)	249	tax price	0.60094874
	123	tax price	-0.323578975
	126	tax price	2.146177206
Paff (2005)	780	dummy variable	2.529874
	780	dummy variable	3.739374
	780	dummy variable	2.622657
	780	dummy variable	2.043399
	780	dummy variable	2.573218
	780	dummy variable	1.901837
	780	dummy variable	2.529874
	780	dummy variable	1.99082
	780	dummy variable	2.560064
	780	dummy variable	1.969947
	780	dummy variable	2.972693
	780	dummy variable	2.422433
Park (2002)	52	B-index	-2.35018
	52	B-index	-1.81505
	52	B-index	-1.71799

	52	B-index	-1.67321
Thomas, Manly and Schulman (2003)	7138	dummy variable	0.05
Wang and Tsai (1998)	125	dummy variable	-2.17
	126	dummy variable	-4.29
Wheeler and Wallace (2007)	322	credit rate	0.763852926
	291	credit rate	1.246832235
	322	credit rate	0.569529652
Wu (2005)	117	dummy variable	1.412096964
	117	dummy variable	1.791090996
	117	dummy variable	1.596638655
	117	dummy variable	1.987741394