Measuring the Effectiveness of R&D tax credits in the Netherlands

Boris Lokshin

University of Maastricht and UNU-MERIT
P.O. Box 616, 6200 MD, Maastricht, The Netherlands
b.lokshin@os.unimaas.nl

and

Pierre Mohnen
University of Maastricht, UNU-MERIT and CIRANO
P.O. Box 616, 6200 MD, Maastricht, The Netherlands
p.mohnen@merit.unimaas.nl
(corresponding author: tel +31-43-388 4464, fax +31-43-388 4905)

Abstract

This paper examines the impact of the Dutch R&D fiscal incentive program, known as WBSO, on R&D capital formation. Taking a factor-demand approach we measure the elasticity of firm R&D capital accumulation to its user cost. An econometric model is estimated using a rich unbalanced panel covering the period 1996-2004 with firm-specific R&D user costs varying with tax incentives. Using the estimated user cost elasticity, we examine the impact of the R&D incentive program. We find evidence that the program of R&D incentives in the Netherlands has been effective in reducing the user cost of R&D and in stimulating firms' investment in R&D.

Keywords: R&D tax credits; panel data; crowding out; user-cost elasticity
JEL Classification: O32, O38, H25, H50, C23

Acknowledgement: The analysis for this paper was performed within the project "Evaluation of WBSO: Effects, coverage and execution", commissioned by the Ministry of Economic Affairs of the Netherlands. The authors would like to thank the members of the feedback group for their critical remarks. In particular we had stimulating discussions with Jan Boone, Maarten Cornet, Piet Donselaar, Jeroen de Jong, Luuk Klomp, George van Leeuwen, and Jarig van Sinderen. We also thank the discussant, I. Feller, and the attendees of The Economics of Technology Policy conference in Ascona and the participants of the CBS microdata users' group meeting in Voorburg for their helpful comments. We appreciate Gerhard Meinen's celerity in providing us with the data. This paper represents the personal views of the authors, not necessarily representing the view of the Dutch Ministry of Economic Affairs.

1. Introduction

Just as for investment in physical capital, economic theory predicts that the user cost of R&D is a primary determinant of a firm's decision to invest in R&D. Governments often rely on fiscal incentives to lower the user cost and thereby stimulate business R&D. Market failure in providing firms with sufficient incentives to do R&D often serves as the economic justification of such government programs, which often involve substantial budgets.

Few studies have established the effectiveness of government R&D fiscal programs using the user cost approach with firm-level data. Most of the available evidence comes from the research using US Compustat data. Hall (1993) is one of the first studies of the effectiveness of US Research and Experimental Credit in stimulating firm R&D. Using an unbalanced firm panel for the eighties she obtains a short-run elasticity of R&D flow of -0.8 to -1.5 and a long-run elasticity of -2.0 to -2.7. There have been few studies using firm-level data for other than US countries to estimate the user cost elasticity of R&D. In an early study of Canadian firms, Bernstein (1986) estimated a short-run elasticity of R&D stock of -0.13 and a long-run elasticity of -0.32. By taking a ratio of the change of in the value of the R&D stock and the change of the cost of production resulting from a change in tax policy, he obtains 0.80 dollars in additional R&D for each dollar of tax expenditure. Dagenais et al. (2002) use an unbalanced panel of Canadian firms to estimate a generalized Tobit model with fixed effects to measure the responsiveness of R&D stock to its price. They find a weakly significant short-run elasticity of R&D stock to its user cost of -0.07 and a significant long-run elasticity of -1.09. The long run elasticity is 15 times higher than the short-run elasticity in their study due to a large and highly significant dynamic effect. By comparing the sum of government reimbursement streams and additional R&D flows due to tax incentives, they conclude that one dollar of government R&D support yields 0.98 in additional R&D. Mairesse and Mulkay (2003) estimate an error-correction model on a long panel of French companies to evaluate the effect of tax credit on R&D capital stock. They find a short-run elasticity of R&D with respect to the tax credit portion of the user cost of -0.41 and a large long-run elasticity of -2.33. They use the latter to obtain that 1% increase in the rate of tax credit would lead to 0.46% increase in the desired R&D capital for French firms doing R&D.

The other existing evidence is based on aggregate data. Of those studies based on a user cost of R&D, Hines (1993) and Mamuneas and Nadiri (1996) obtain R&D stock elasticity of around unity. Bloom et al. (2002) using a panel of data for nine OECD countries obtain a smaller, but still significant short-run R&D flow elasticity of -0.14 and a long-run elasticity of -1.09. A critical discussion of the state of the art in this literature is provided by Hall and van Reenen (2000).

In this paper we aim to add to this growing literature by examining the impact of the R&D incentive program (the so called WBSO Act[1]) on R&D capital formation in Dutch firms. A first evaluation of the effectiveness of WBSO was conducted by Brouwer et al. (2002) using data from two cross-sections of 1996 and 1998, and regressing business R&D on lagged WBSO disbursements. They find that a Euro of tax support for R&D yields slightly more than one Euro (1.02) in additional R&D. In our empirical analysis we take a factor-demand approach using a new, rich, firm-level unbalanced panel dataset covering 1996-2004, constructed from the annual R&D surveys, production statistics from the Central Bureau of Statistics and R&D tax incentives data from SenterNovem, the administrative agency in charge of R&D tax incentives. The richness of the merged dataset allows us to construct R&D price indexes and year- as well as firm-specific R&D user costs as a function of R&D tax incentives. By constructing both marginal and average user cost indexes we aim to model different scenarios of firms' response to policy changes. Our firm-specific data allows a good measurement of the user cost by providing sufficient variation in the indexes in both the cross-section and time dimensions to improve the measurement of the effects of the fiscal incentives program.

Our dynamic R&D factor demand model inspired by Chirinko, Fazzari, Meyer (1999) and Mairesse and Mulkay (2003) is based on a CES technology and a partial adjustment mechanism. We apply it to estimate the elasticity of firm R&D capital formation to its user cost. We consider a number of different specifications with various lag-structures allowing for computation of both short- and long-run effects.

Precise estimation of the user cost elasticity of R&D capital stock is important in evaluating the effectiveness of subsidy programs. In this study we conduct such evaluation using a usual cost-benefit analysis[2] by comparing the extra firm R&D induced by the incentive program to its cost to the government. Our structural modeling approach allows us to perform a number of policy simulations to examine the cost-benefit of the overall incentive program and some of its components. The ability to perform policy experiments gives the user-cost based structural model an advantage over the recently popular matching estimator approach, which does not lend itself easily to policy experiments and in most applications is based on cross-sectional data.

[1] WBSO is an acronym for The Wage tax and Social Insurance Act (Wet bevordering speur - en ontwikkelingswerk) introduced in 1994 to stimulate research and development in the Netherlands. In 2005 the Dutch government spent about 400 million Euros on WBSO.

[2] Hall and Van Reenen (2000) point out that there is a second (more difficult to implement) approach to evaluate the effectiveness of tax credit schemes which requires a comparison of "the marginal return of private R&D at societal level to the opportunity cost of using the extra tax dollars in another way" (p. 456).

The rest of the paper is organized as follows. Section 2 lays out our modeling approach. Section 3 describes the way we have assembled our data set and explains how we have constructed the variables used in the empirical analysis. Section 4 presents our empirical results. We discuss several regression specifications, leading to our preferred specification. We also discuss a number of alternative specifications and the robustness checks that we have performed. In section 5 we measure the effectiveness of the tax credits in stimulating R&D in the Netherlands. Finally, Section 6 concludes. In two appendices we explain in detail the construction of the user cost of R&D for the Netherlands and the difference between the present study and the study for the Ministry of Economic Affairs (2007).

2. **Empirical model**

This section outlines the model that we use in the empirical analysis. We take the approach of Chirinko et al. (1999), Hall and van Reenen (2000), and Mairesse and Mulkay (2004), and start from a CES approximation to the true production function:

$$Q_{it} = F_t(K_{it}, X_{it}) = \gamma[\beta K_{it}^{-\rho} + (1-\beta) X_{it}^{-\rho}]^{-\nu/\rho} \quad (1)$$

where Q_{it} stands for output, K_{it} for the end of period R&D stock, X_{it} for the other inputs, and γ (a scale factor), β (the distribution parameter), ν (a measure of the returns to scale) are parameters to be estimated that characterize the technology, as well as ρ that enters the expression for the elasticity of substitution (σ) between R&D stock and the other inputs and is given by $\sigma = 1/(1+\rho) \geq 0.$ If we assume that the R&D stock becomes immediately productive and there are no adjustment costs or other sources of lagged adjustment, and static expectations on prices and output, we obtain the first-order condition of the profit maximization

$$\nu\beta Q_{it}^{(1+\rho/\nu)} \gamma^{-\rho/\nu} K_{it}^{-(\rho+1)} = u_{R,it} / p_{Q,it} \quad (2)$$

Solving this equation for the optimal long-term R&D stock yields:

$$K_{it}^{*} = A Q_{it}^{\zeta} (u_{R,it} / p_{Q,it})^{-\sigma} \quad (3)$$

where A is a constant and $\zeta = \sigma + \frac{\sigma}{\nu}(\frac{1}{\sigma} - 1)$. Notice that the exponent of output is equal to 1 if returns to scale are constant or if the elasticity of substitution is equal to 1 (a Cobb-Douglas technology). Equation (3) expresses the optimal demand for R&D capital in terms of its price (the user cost) relative to the price of output, and the volume of output. By taking the logarithm of both sides of (3) and denoting the log of variables by small letters we obtain:

$$k_{it}^{*} = a + (\sigma + (1-\sigma)/\nu)q_{it} - \sigma(u_{R,it} - p_{Q,it}). \quad (4)$$

The volume of output and the output price are difficult to measure at the micro level. What is generally done is to use industry-level prices. To eliminate the need to observe individual output prices, we introduce an output demand equation with constant price elasticity, so as to obtain a formulation involving nominal output, following the example of Klette and Griliches (1996), also adopted by van Leeuwen and Klomp (2006) and Mairesse and Mulkay (2003). We assume that the enterprise faces a demand curve given by

$$Q_{it} = Q_{It}\left(\frac{P_{Q,it}}{P_{It}}\right)^{-\varepsilon} \quad (5)$$

where Q_{It} is the industry demand and P_{It} the industry price in period t, and ε is the price elasticity in absolute value ($\varepsilon > 0$). If we invert the demand function (5) we can write

$$P_{Q,it} = Q_{it}^{-1/\varepsilon} Q_{It}^{1/\varepsilon} P_{It} \quad (6)$$

The resulting industry-price deflated output is

$$V_{it} = P_{Q,it} Q_{it} / P_{It} = Q_{It}^{1/\varepsilon} Q_{it}^{1-1/\varepsilon},$$

and the demand function can also be written as

$$Q_{it} = V_{it}^{\mu} Q_{It}^{1/(1-\varepsilon)} \quad (7)$$

where $\mu = (1-1/\varepsilon)^{-1}$ is the price markup over marginal cost in imperfect competition.

If, after taking logs, we plug (6) and (7) into (4), we get

$$k_{it}^{*} = a + \phi v_{it} - \sigma(u_{R,it} - p_{I,it}) + \gamma q_{I,it} \tag{8}$$

where $\phi = \sigma + \mu(1-\sigma)/\nu$, and $\gamma = (1-\mu)(1-\sigma)/\nu$. The resulting expression gives the steady-state relationship (in logarithms) between a firm's optimal R&D stock, its real output, its user cost relative to the industry price, and the industry output[3].

Equation (8) depicts a long-run relationship. Many empirical studies have shown that there are adjustment costs associated with the accumulation of the stock of R & D (having to do with setting up and organizing the research team, financing the project, or elaborating a research program). It is costly to adjust the stock of knowledge too quickly and therefore the optimal investment outlays depend on the shape of the adjustment cost function. Other theoretical models justify a dynamic formulation (i.e. with lagged terms) of the investment equation on the basis of the existence of various lags in perception, decision-making, and implementation of investment projects.

The exact expression for the optimal path of R&D expenditures, derived from an inter-temporal optimization problem depends then on the assumptions made regarding the adjustment cost function, the "time to build", and the process underlying the expectation formations. Such structural models are theoretically appealing but practically not very rewarding. To quote Hall and van Reenen (2000, p. 460) "Structural investment models for physical capital had a poor record of success in empirical testing whether of q-models, Euler equations or Abel-Blanchard variety. Although various attempts have been made to estimate these more structural forms none have been conspicuously successful." An alternative, more flexible, strategy is to start from a more ad hoc dynamic formulation or to let the data reveal the dynamic formulation without specifying the essence of the dynamics.

To introduce a parsimonious long-run relationship, allowing the estimation of short-term and long-term effects of the user cost of R&D and indirectly of tax credits on R&D, several approaches have been used in the literature. One is to adopt an autoregressive distributed lag (ADL) specification and to

[3] Notice that the industry output disappears from equation (8) when either $\sigma = 1$ (Cobb-Douglas technology) or $\mu = 1$ (perfect competition). Parameter ϕ equals 1 if either $\sigma = 1$ or $\mu = 1$ and $\nu = 1$ (constant returns to scale).

express a resulting equation in an error-correction (EC) form. This model is estimated by Jaumotte and Pain (2005) and Mairesse and Mulkay (2003). Because of the individual effect in (8), there would still be a problem of endogeneity in the resulting EC equation and at least the lagged endogenous variable would have to be instrumented. A simpler approach, taken by Bloom, Griffith and van Reenen (2002) is to make equation (8) dynamic by introducing a lagged dependent variable term.

Another way to introduce dynamics in the relationship of R&D to its user cost is to consider that the investment in R&D of period t is the result of adjustments in the desired stocks of many preceding periods, as in Chirinko et al. (1999). Investment is composed of a replacement investment (R_{it}^r) and a net investment (R_{it}^n). The former is proportional to the R&D stock at the beginning of the period: $R_{it}^r = \delta K_{i,t-1}$. The latter represents the change in the R&D stock: $R_{it}^n = K_{it} - K_{i,t-1}$. Hence we can write

$$\frac{R_{it}}{K_{i,t-1}} = \frac{R_{it}^r + R_{it}^n}{K_{i,t-1}} = \delta + (\frac{K_{it}}{K_{i,t-1}} - 1) . \qquad (9)$$

We can consider the relative changes in the R&D stocks as a weighted mean of the relative changes in the desired R&D stocks:

$$\frac{K_{it}}{K_{i,t-1}} = \frac{\Delta K_{it}}{K_{i,t-1}} + 1 = \prod_{h=0}^{H} \left(\frac{K_{i,t-h}^*}{K_{i,t-h-1}^*} \right)^{\mu_h} = \prod_{h=0}^{H} \left(\frac{\Delta K_{i,t-h}^*}{K_{i,t-h-1}^*} + 1 \right)^{\mu_h} . \qquad (10)$$

By taking logs of both sides of (10), using the approximations ln(1+x) $\approx$ x and $\Delta x / x \approx d \ln x$, we can write (10) as

$$d \ln K_{it} = \sum_{h=0}^{H} \mu_h d \ln K_{i,t-h-1}^* . \qquad (11)$$

Changes in the R&D stock are therefore expressed as a weighted mean of the relative changes in the desired R&D stocks of the past. We can rewrite (11) as

$$\frac{R_{it}}{K_{i,t-1}} = \delta + \phi \sum_{h=0}^{H} \mu_h dv_{i,t-h} - \sigma \sum_{h=0}^{H} \mu_h (du_{Ri,t-h} - dp_{Ii,t-h}) + \gamma \sum_{h=0}^{H} \mu_h q_{Ii,t-h} + \varepsilon_{it} \qquad (12)$$

after appending a random error term and remembering that the variables in small letters represent variables in logarithms.

We could also add an individual effect to (12), however if we consider that the individual effect should enter the level equation (8), it should be removed after first-differencing. Actually estimation results confirm that the individual effects are insignificant in specification (12)[4]. The slope coefficients can be interpreted as elasticities because the expression on the right-hand side of (12) (except for the intercept) represents the growth rate of the R&D stock. The $\sigma\mu_h$ (h=0,1...,H) coefficients represent the elasticities of the R&D stock with respect to past user costs. The short-run elasticity is given by $-\sigma\mu_0$ and the long-run elasticity is given by $\sum_{h=0}^{H} -\sigma\mu_h$.

One worry is that the contemporaneous change in the user cost in (12) is likely to be endogenous because the tax incentive schedule depends on the amount of R&D undertaken. In this case the OLS estimates of (12) are upwardly biased. Instead, we use an instrumental variables approach, which is explained in more detail in Section 4.

Since we have few adjacent observations in the time dimension, we shall assume that the μ_h follow a Koyck scheme of exponentially declining coefficients $\mu_h = \mu\lambda^h$ with h=0,1, …, and λ<1. This would allow us to specify an infinitely long distributed lag with only one parameter (λ) and one lagged expression instead of working with a finite distributed lag, which we can only estimate at the price of reducing the length of our sample. Now we can write (12) as

[4] The estimated σ_u in equation (12) is zero, when estimated with random effects.

$$\frac{R_{it}}{K_{i,t-1}} = \delta + \phi\sum_{h=0}^{\infty}\mu_h dv_{i,t-h} - \sigma\sum_{h=0}^{\infty}\mu_h(du_{Ri,t-h} - dp_{Ii,t-h}) + \gamma\sum_{h=0}^{\infty}\mu_h q_{Ii,t-h} + \varepsilon_{it}$$
$$= \delta + \varphi\frac{\mu\, dv_{it}}{I-\lambda L} - \sigma\frac{\mu(du_{Rit} - dp_{Iit})}{I-\lambda L} + \gamma\frac{\mu\, q_{Iit}}{I-\lambda L} + \varepsilon_{it}. \quad (13)$$

Equation (13) can also be rewritten as

$$\frac{R_{it}}{K_{i,t-1}} = (1-\lambda)\delta + \lambda\frac{R_{i,t-1}}{K_{i,t-2}} + \varphi\mu\, dv_{it} - \sigma\mu(du_{Rit} - dp_{Iit}) + \gamma\mu q_{Iit} + (\varepsilon_{it} - \lambda\varepsilon_{i,t-1}) \quad (14)$$

The short-run elasticity of R&D stock with respect to the user cost of R&D is given by $-\sigma\mu$. The long-run elasticity is given by $-\sigma\mu/(1-\lambda)$. Notice that the error term now follows a MA(1) process. Because of the simultaneity between the user cost and the amount of R&D we have to instrument for the contemporaneous change in the user cost of R&D.

3. **Data and descriptive statistics**

Data sample

The empirical analysis makes use of CBS's annual CIS/R&D surveys in combination with production statistics (PS) and administrative data from SenterNovem (SN) regarding WBSO. The R&D surveys contain information on firms' R&D expenditures and their breakdown by type, and the PS database contains information on output, employment and output deflators. The SN database contains firm information on the actual annual total R&D wage bill and the amount of tax deductions that SN eventually granted[5]. The three data sources and the process of merging them are explained in detail in Ministry of Economic Affairs (2007). In the estimation of the effects of WBSO on firm R&D we use an unbalanced panel of annual firm observations between 1996 and 2004. The WBSO facility primarily targets small and medium sized enterprises. Among some 10200 firms that applied for WBSO in 2004, 46% had fewer than 10 employees, while the share of firms with 10-50 employees

[5] The R&D fiscal incentive facility in the Netherlands is absolute, meaning that firms can apply for the wage tax deductions based on their annual R&D wage bill. As a result the cost of R&D employees for a firm decreases and the taxable income increases. A portion of the tax deductions are therefore recovered by the state. There are two brackets with the corresponding rates of 42% on the first 110 thousand Euros in firm R&D wage expenditure; followed by 14% on the remaining amount below the ceiling, set at 7.9 million (data are for 2004). An overview of the WBSO parameters is given in Table 2.

was 32% and the shares of medium-sized firms (50-250 employees) and large firms (250 and more employees) were 16% and 5% respectively[6]. Enterprises from all manufacturing and service sectors can apply for WBSO. In 2004 there was the following distribution of WBSO users by sector: agriculture (7%), food (5%), chemicals (11%), machines (29%), other manufacturing (22%) ICT (11%), and other services (14%). This distribution has stayed more or less constant from 1996 till 2004 (Ministry of Economic Affairs, 2007).

Not all R&D performers apply for WBSO tax credits. More than 80% of the larger firms (with more than 250 employees), about 80% of medium-sized firms and about 70% of the smaller firms (with fewer than 50 employees) apply on average for the WBSO facility. However, among those firms that have more than 5 full time R&D employees, more than 88% use the WBSO facility.

For all size classes the coverage has gradually increased from the inception of the fiscal incentives program in 1994 to 2004, both in terms of the number of firms applying and the number of total applications by these firms. From 1997 to 2004 there was a 29% increase in granted applications for the tax credits.

When we split the number of observations in our sample in three categories of firm size we see that apart from the last cleaning stage[7] the distribution of our sample across size classes remains unaffected. The middle size group (50 to 250 employees) represents around 59%. Largest firms (over 250 employees) are over-represented in our sample. The smallest size group (fewer than 10 employees) is under-represented due to the absence of innovation and R&D survey data from CBS over the whole period for firms with less than 10 employees. According to SenterNovem, 70% of the WBSO receivers are firms with less than 250 employees. In our final sample the number of observations from firms in that size class is close to 60% of the total. In the factor demand model of R&D that we propose, we have to eliminate firms with non-contiguous R&D observations in order to construct R&D stocks. In the end our dataset covers only a fraction of the total population of WBSO receivers: on average, across years, firms in our sample account for 15% of total WBSO expenditures and almost 25% of all R&D performed in the Netherlands.

[6] The share of the smallest firms (fewer than 10 employees) has grown in the period from 1995 to 2004 from 30% to 46%. The shares of all other size classes have declined in the same period: for size class 10-50 employees from 37% to 32%; for 5-249 employees from 24% to 16% and that of more than 250 employees from 9% to 5%, respectively.

[7] We selected only those firms that perform R&D on a continuous basis, the so called 'hard-core' R&D performers because in odd years CBS only collects data for 'hard-core' R&D performers. We also selected only those firms that and have a positive R&D in all three mentioned data sources. The use of lags in the dynamic econometric specification as well as the construction of R&D stock further eliminates firms with non-contiguous observations over time.

Table 2 lists the main parameters of the WBSO program for the period covered by our estimation sample. The WBSO budget has increased by almost 80% and the number of approved for funding projects has grown by almost 60% from 1996 to 2004.

Variables

In our empirical model corresponding to equations (12) and (14), we use the following variables.

The dependent variable is the firm R&D expenditures R divided by its R&D stock K in the previous period. Own firm R&D expenditures are taken from the combined CIS/R&D data file (the SenterNovem dataset contains data on R&D labor costs only, not total R&D expenditures).

[INSERT TABLE 1 AND TABLE 2 HERE]

According to our theoretical model, the two main explanatory variables are contemporaneous and lagged growth rates in the user cost of R&D, Δu_R and in value added, Δv. Table 1 provides descriptive statistics on the variables used in the estimation. As explained in the modeling section, a negative relation is expected between the user cost and the firm's R&D investment and a positive relationship between output and R&D investment rate. The construction of the user cost is explained in detail in appendix A. To construct the user cost of R&D, we use the information about the R&D cost composition, provided by CBS.

[INSERT TABLE 3 HERE]

Table 3 shows the average user cost (constructed using expression A4) of R&D and its components for all the firms in our sample. The user cost in the absence of R&D tax incentives has increased by 30% between the beginning and end year in our sample. The average WBSO tax credit has increased from 17.3 to 19.4 percent. This slight increase is attributable mostly to increases in the two WBSO ceilings and a resulting compositional change of the firms with respect to the WBSO scheme: (i) an increase of the percentage of firms applying for WBSO from 66.4% in 1997 to 73.4% in 2004, (ii) an increase in the percentage of non-starter R&D performers that fall under the first bracket ceiling from 12.8% in 1997 to 36.3% in 2004, and (iii) an increase in the percentage of non-starter R&D performers that fall between the first bracket and the second bracket ceiling from 16.5% in 1997 to 36.6% in 2004.[8]

[8] Had we used expression A5, i.e. the marginal WBSO rates instead of the average WBSO rates in the user cost of R&D, the WBSO tax credit portion of the user cost would have tripled from 1997 to 2004.

Column (3) contains the average B-index, including the WBSO and other R&D tax incentives. Between 1997 and 2004 the overall R&D tax incentives have decreased the R&D user cost by 12%. This percentage is lower than the increase in the WBSO because the increase in the corporate income tax rate partly reduces the usual deductions due to expensing and depreciation allowances. Column (4) presents the user costs of R&D obtained as the product of the corresponding averages in columns (1) and (3). The nominal user cost has increased from 0.258 to 0.314, i.e. by 22% between 1997 and 2004. The increase in inflation and in the real interest rate has been tempered by the increase in R&D tax incentives. In column (5) we present the average user cost of R&D without the WBSO tax credit. We see that without WBSO the user cost of R&D would have increased by 25%. The user cost of R&D would be on average higher by 18 to 24 % without WBSO.

4. Econometric Results

In this section we present regression estimates from our empirical equations (12) and (14). The main results are reported in Table 4. The Hausman test rejects the null hypothesis that the contemporaneous Δu_{Rit} is exogenous ($\chi^2(1)$ is 10.3) and, therefore, instrumental variables techniques are required. We instrument for the contemporaneous growth rate of the user cost of R&D in (12) and (14) with lagged level values of the user cost and output because of a possible simultaneity between R&D expenditures and the user cost of R&D, and also for the lagged dependent variable in equation (14) because of the MA(1) nature of the error term.

[INSERT TABLE 4 HERE]

We estimate equations (12), model I, and (14), model II, without individual effects. There is no particular reason to include an individual effect as the equations are already in first-differences and the depreciation of R&D as well as the adjustment speed towards the desired R&D stocks are supposed to be constant across firms. Indeed, when we introduce the individual effects, the variance of the random error term turns out to be insignificant. In equation (12) we experiment with up to three lags in the growth rates of the user cost. Each additional lag reduces the size of the sample. Alternatively, we can assume a longer lag structure by modeling an infinite geometrically distributed lag as in (14), but then we lose observations because of a one-period lag in the dependent variable.

We use a Sargan test to test for over-identifying restrictions. We cannot reject the validity of the instruments in each of the estimated models reported in Table 4. When we include the lagged level

value of the dependent variable as an additional instrument in model I, the coefficient on the Δu_{Rit} increases, but the model becomes over-identified, i.e. Sargan test rejects these additional instruments. In addition, when we use a difference-in-Sargan C statistics to test exogeneity of our instruments, we cannot reject it in any of the models. We have also used difference-in-Sargan test to check whether the growth in output $\Delta v_{i,t}$ is endogenous and needs to be instrumented. We could not reject the null hypothesis that this variable is exogenous. We also checked the validity of our instruments using Anderson test and Cragg-Donald F statistic. Stock and Yogo (2005) have computed the critical values for the Cragg-Donald F statistic which are also reported by the instrumental variables estimator we used (Baum et al., 2007). According to these tests the instruments perform well, i.e. the computed F statistic rejects the null hypothesis that the instruments are weak.

Some of the reported tests can be sensitive to the presence of heteroskedasticity, in which case a more efficient GMM or GMM-CUE estimator can be used. To check this, we perform several heteroskedasticity tests on residuals in all our models. We use Pagan and Hall's (1983) general test of heteroskedasticity for instrumental variables (IV) estimation as well as the standard heteroskedasticity test of White/Koenker[9]. These tests do not reject the assumption of homoskedasticity of residuals in all versions of our model.

The results from a distributed lag model with one, two and three lags, listed in columns (2) and (3) and (4), respectively, yield individually significant coefficients for the user cost of R&D. When including only two lags we get significant elasticities for both current and one-period lagged user cost[10]. The model selection criteria definitely reject the immediate adjustment model (column 1 of model I). The R-square is the highest in the model with 2 lags while the Akaike information criterion gives the preference to Model II. In Model I it gives preference to the model with 2 lags.

It is worth noticing that the short-run and long-run price elasticities are not significantly different in (2) and (5) although they are based on a different number of observations. This observation gives

[9] These tests were performed using the Stata ivhettest program developed by M. Shaffer.

[10] In the model selection process we experimented with several control variables. We included controls for business cycle influences on R&D investment by using industry-specific business cycle indicators: for investment potential (i.e. solvability and return on total assets) and indicators for perceived competition, turbulence and economic development. These variables were constructed and provided to us by EIM. None of these control variables had a significant coefficient. We also tried to control for a possible size effect in the R&D investment rate by including the log of the number of employees as an additional regressor. Since size already appears as an explanatory variable in the desired growth rate of the R&D stock, the size effect would capture differences in the speed of adjustment of R&D stock. This coefficient is, however, also insignificant. To include more firm specific control variables we would have to resort to the CIS surveys, which are only available in even years. We have refrained from doing so as not to lose too many observations.

credence that our results are robust. The short-run price elasticities of R&D stock are given by σ_0. A one percent decrease in the contemporaneous user cost of R&D increases the R&D stock by 0.27 percent in (3), 0.28 percent in (5). The price elasticity after one period is -0.12 in column (3) and in the geometrically declining distribution assumed in column (5) it drops to -0.17 (0.283 x 0.603) percent.

The long-run elasticity, computed as the sum of distributed lag coefficients on $du_{Ri,t-h}$ in model I is -0.39 in our preferred specification and is statistically significant. The long-run elasticity implied by model II is -0.72, and is also statistically different from zero.

We ran a number of alternative specifications to test the sensitivity of our results. Given the R&D tax incentives structure in the Netherlands, we used the expression (A4) to construct the B-index contained in the user cost measure. This expression is a weighted average of the first and second bracket rates. According to this expression, a firm that is situated in the second bracket but below the ceiling would receive a wind-fall profit if the rate of the first bracket or the length of the first bracket was extended, even if all other parameters remained unchanged. Such changes occurred several times during 1996-2004, the period covered in our panel. For example, in 2001 the length of the first bracket was extended from € 68,067 to € 90,756 and in the same year an additional higher bracket for starters (60% as opposed to 40% for the rest) was introduced.

One of the premises of economic theory is that economic agents take decisions at the margin. Therefore, one could argue that firms decide on their marginal R&D investments on the basis of the marginal WBSO rates, hence for firms that are in the second bracket it would be that rate and only that rate which matters. This would mean that the wind-fall profits would not affect firms' R&D decisions. If we assume that only the marginal WBSO rates matter then we would use the expression for the B-index given by formula (A5).

It has been argued in the capital investment literature that liquidity can affect firms' capital investment decisions (Fazzari et al., 1988). Liquidity effects may be more important for investment decisions in non-tangible assets like R&D which is relatively more risky compared to the capital investment. Hall (1992), Hao and Jaffe (1993), Harhoff (1998), Himmelberg and Petersen (1994), among others, report some empirical evidence that liquidity has an effect on firm R&D investment. Therefore we argue that firms decide on their R&D investment based on the average user cost of R&D (expression A4), so that firms in the second bracket would increase their R&D even if the rate of the first WBSO bracket

increases, providing them with more liquidity. Anecdotal evidence also suggests that firms consider that this windfall profit is WBSO money which gets reinvested in R&D[11].

To compare the outcomes of our model under marginal and average user cost approach, we re-estimated our model under the marginal user cost assumption. In this case the constructed user cost is higher and the effective tax credits part is lower. This change leads to a higher variation, i.e. a tripling of the tax credits part in the user cost of R&D expression over the estimation period. The estimated short-run elasticity corresponding to columns 1 to 3 of Table 4 decrease to 0.22; 0.13; and 0.29 and the long-run elasticity ranging between 0.22 and 0.54. These elasticities are somewhat lower but not different in a statistical sense from those reported in Table 4.

In our specifications (12) and (14) output is in real (industry deflated) terms and the user cost of R&D is deflated by the industry price of output. We have opted for these specifications as explained in the modeling section. We checked whether the use of nominal variables together with time and/or industry dummies would make a difference. The use of nominal user cost with time dummies results in somewhat higher elasticities for both the user cost and output variables.[12] We also checked whether a specification with time and industry dummies and nominal user costs would yield similar results as one with real user costs and output but no time and industry dummies, because the deflators vary only over time and industry. The latter experiment yields significant coefficients but similar orders of magnitude.

5. Effectiveness of tax credits to R&D

We are interested in evaluating the effectiveness of the whole WBSO program. For that we shall compare the present situation with WBSO to a fictive scenario without WBSO. In the absence of a proper cost-benefit calculation including all costs and benefits related to such a program, the usual way to assess the efficiency of R&D tax incentives consists in computing the so-called "bang for the buck" (BFTB). By that is meant by how much private R&D increases per Euro of R&D tax receipts foregone. It is greater than 1, R&D tax incentives are considered to be efficient in stimulating

[11] Interviews with companies' R&D managers were conducted in order to solicit feedback on WBSO effectiveness. The outcomes of the interviews suggest that WBSO tax rebates are reinvested back into firms' R&D (Ministry of Economic Affairs, 2007).

[12] Those results are presented in (Ministry of Economic Affairs, 2007). Although the results are statistically not very different there, it makes sense to use the available industry deflators instead of the just the overall deflator in equation (5).

additional R&D. A value smaller than 1 means that part of the money received from tax incentives substitutes for private financing[13].

In our model based on the user cost of R&D the price elasticity has no longer a direct connection to the BFTB[14]. To obtain a Euro for Euro magnitude we have to evaluate the R&D (in Euros) ensuing from a change in the user cost of R&D following a suppression of the WBSO program to the money it would save the government for no longer supporting the program. Instead of having $\partial R/\partial WBSO$ directly, we can obtain a Euro per Euro effect by calculating $(\partial R/\partial u)/(\partial WBSO/\partial u)$, where WBSO stands for WBSO disbursements. In our experiment we will simulate the reduction in R&D in case of suppression of the WBSO compared to the present situation containing the tax incentives program.

We assume that the present scenario with the WBSO corresponds to a steady state, starting in period 0 with an inherited R&D knowledge stock of K_0. The only R&D that gets spent serves to keep the R&D stock constant. In the new scenario the government decides to remove the whole WBSO scheme, which leads to an increase in the user cost of R&D and to firms wanting to decrease their optimal stock of knowledge. We now have a new desired R&D stock. Following this scenario firms decrease their R&D investment and at the same time government no longer needs to support the WBSO. When the adjustment to the new optimal R&D stock is completed firms have reached a new steady state with lower R&D expenditures. The following table summarizes the old and the new trajectory of R&D flows and R&D stocks from period 0 onwards for a particular firm.[15] To ease the notation we drop firm subscript i.

[13] The threshold value of 1 will change if we include external effects and side effects in the benefits of the tax program and administrative and implementation costs for the firms as for the government in the additional costs due to the tax program.

[14] If we regress private R&D expenditure on the WBSO disbursements, then the regression coefficient gives directly the "bang for the buck", i.e. by how much at the margin one Euro of R&D tax credits stimulates private R&D. This is the approach taken in Brouwer et al., (2002). The authors obtain a BFTB of 1.01 using the labor R&D expenditures as a dependent variable. For comparison, we re-estimated a similar model with the fixed effects and obtained a BFTB value of 1.27. This approach suffers from simultaneity between tax credits and own R&D expenditures and does not distinguish between short-run and long-run effects.

[15] Since we start from the same stock of R&D capital in both the new and old trajectory in the first period after the policy shock the differences in R&D outlays equals the difference in R&D stocks, while the replacement investment is the same. In period 1 and afterwards the difference in R&D flows are due to differences in net and replacement investment. When the new steady state is reached, the difference in R&D outlays and the corresponding costs to the government correspond only to differences in replacement investment.

	Old scenario (with tax credits)		New scenario (after removal of tax credits)	
periods	R&D flow	R&D stock	R&D flow	R&D stock
0	$R_0 = \delta K_0^*$	K_0^*	$R_0 = \delta K_0^*$	K_0^*
1	$R_1 = \delta K_0^*$	$K_1^* = K_0^*$	$\tilde{R}_1 = \delta K_0^* + (\tilde{K}_1^* - K_0^*)$	$\tilde{K}_1^* = K_0^* + (\partial K_1 / \partial u_R)\Delta u_R$
2	$R_2 = \delta K_0^*$	$K_2^* = K_0^*$	$\tilde{R}_2 = \delta \tilde{K}_1^* + (\tilde{K}_2^* - \tilde{K}_1^*)$	$\tilde{K}_2^* = \tilde{K}_1^* + (\partial K_2 / \partial u_R)\Delta u_R$
3	$R_3 = \delta K_0^*$	$K_3^* = K_0^*$	$\tilde{R}_3 = \delta \tilde{K}_2^* + (\tilde{K}_3^* - \tilde{K}_2^*)$	$\tilde{K}_3^* = \tilde{K}_2^* + (\partial K_3 / \partial u_R)\Delta u_R$
4	.	.	.	.

The derivative $\partial K_j / \partial u_R$ represents the change in desired R&D stock that occurs j-1 periods after the change in WBSO.

To find out how much R&D arises from a WBSO tax change, we have to compute the differences in R&D flows (or expenditures) from period 1 onwards till infinity between the two scenarios, where the flows of each additional year are discounted by 1/(1+r) vis-à-vis the previous year. This in our particular case is equal to[16]

$$\sum_{t=1}^{\infty} (\tilde{R}_t - R_t)/(1+r)^{t-1} = \sum_{t=1}^{\infty} \left[\delta \left(\frac{\partial K_1}{\partial u_R} + ... + \frac{\partial K_{t-1}}{\partial u_R} \right) + \frac{\partial K_t}{\partial u_R} \right] \Delta u_R \Big/ (1+r)^{t-1} \qquad (15)$$

In expression (15) we have

$\frac{\partial K_1}{\partial u_R} = \sigma\mu \frac{K_1}{u_R}$, where $\sigma\mu$ is the estimated user cost elasticity of R&D stock in the first period; $\frac{\partial K_2}{\partial u_R} = \sigma\mu\lambda \frac{K_2}{u_R}$, where λ is the estimated parameter of the adjustment process; $\frac{\partial K_3}{\partial u_R} = \sigma\mu\lambda^2 \frac{K_3}{u_R}$, etc.; δ is depreciation parameter, taken to be 0.15 (15%) and r is the interest rate, on average 0.03 (3%) and Δu_R is the discrete difference in the user cost evaluated at the new and old scheme, i.e. with and without tax credit expression[17] in it and is given by the following expression:

[16] Because $\tilde{K}_{t-1}^* = K_0^* + (\partial K_1 / \partial u_R + \partial K_2 / \partial u_R + ... + \partial K_{t-1} / \partial u_R)\Delta u_R$ we can write

$\tilde{R}_t - R_t = \delta(\tilde{K}_{t-1}^* - K_0^*) + (\partial K_t / \partial u_R)\Delta u_R = \delta\,(\partial K_1 / \partial u_R + \partial K_2 / \partial u_R + ... + \partial K_{t-1} / \partial u_R)\Delta u_R + (\partial K_t / \partial u_R)\Delta u_R$

$= [\delta(\partial K_1 / \partial u_R + \partial K_2 / \partial u_R + ... + \partial K_{t-1} / \partial u_R) + \partial K_t / \partial u_R]\Delta u_R$

[17] If we model the user cost of R&D on the basis of marginal WBSO tax rates instead of average WBSO the B-index that enters the computation of the user cost is calculated using expression A5, given in the appendix

$$\Delta u_R = -P_R(r+\delta)w^L D_1\left[a\min\left(\frac{R_L^1}{w^L R},1\right)+db\min\left(1-\frac{R_L^1}{w^L R},\frac{c}{w^L R}\right)\right]$$

where $a=\omega_1^1(1-D_2)+\omega_2^1 D_2$, $b=\omega_1^2(1-D_2)+\omega_2^2 D_2$, $c=(R_L^2-aR_L^1)/b$, $D_1=1$ if the firm uses the credit facility, else $D_1=0$; $D_2=1$ if the firm is eligible for a starter's rate, else $D_2=0$ and $d=1$ if $w^L R>R_L^1$, else $d=0$. Parameters R, w^L, D_1 and D_2 are firm-specific. The values of the remaining parameters in the expression for Δu_R which are also used in the computation of the user cost: ω_1^1 (first bracket tax rate for non-starters), ω_2^1 (first bracket tax rate for starters), ω_1^2 (second bracket tax rate for non-starters), ω_2^2 (second bracket tax rate for starters), R_L^1 (length of the first bracket), R_L^2 (ceiling) are given in appendix A.

Substituting these in (15) gives

$$\sum_{t=1}^{\infty}(\tilde{R}_t-R_t)/(1+r)^{t-1}=\sum_{t=1}^{\infty}\frac{\sigma\mu\Delta u_R}{u_R(1+r)^{t-1}}\left[\delta\left(K_1+(\lambda)K_2+\ldots+\left(\lambda^{t-2}\right)K_{t-1}\right)+\left(\lambda^{t-1}\right)K_t\right] \qquad (16)$$

In expression (16) K_t, Δu_R and u_R are firm-specific but we omit index i and R for expositional purposes. We evaluate the elasticity $\frac{\partial K_t}{\partial u_R}$ at the corresponding firm-specific value of the R&D stock in each period, i.e. K_t, which can be computed as

$$K_t=\frac{K_{t-1}}{1-\sigma\mu\Delta u_R\lambda^{t-1}/u_R}$$

Here $0<\lambda<1$, which guarantees that (16) converges to a new steady state.

The total cost to the government to support the R&D tax credit program is given by W_t. The difference in government costs between the two scenarios is given by

$$\sum_{t=1}^{\infty}(\tilde{W}_t-W_t)/(1+r)^{t-1}=-\sum_{t=1}^{\infty}\left[a\min(w^L\tilde{R}_t,R_L^1)+db\min\left\{(w^L\tilde{R}_t-R_L^1),c\right\}\right] \qquad (17)$$

We can compute (17) for each period iteratively using the expression $\tilde{R}_t = \delta \tilde{K}^*_{t-1} + (\tilde{K}^*_t - \tilde{K}^*_{t-1})$, and assuming that w^L, i.e. the labor composition of the R&D costs, does not vary with the tax credit rate.

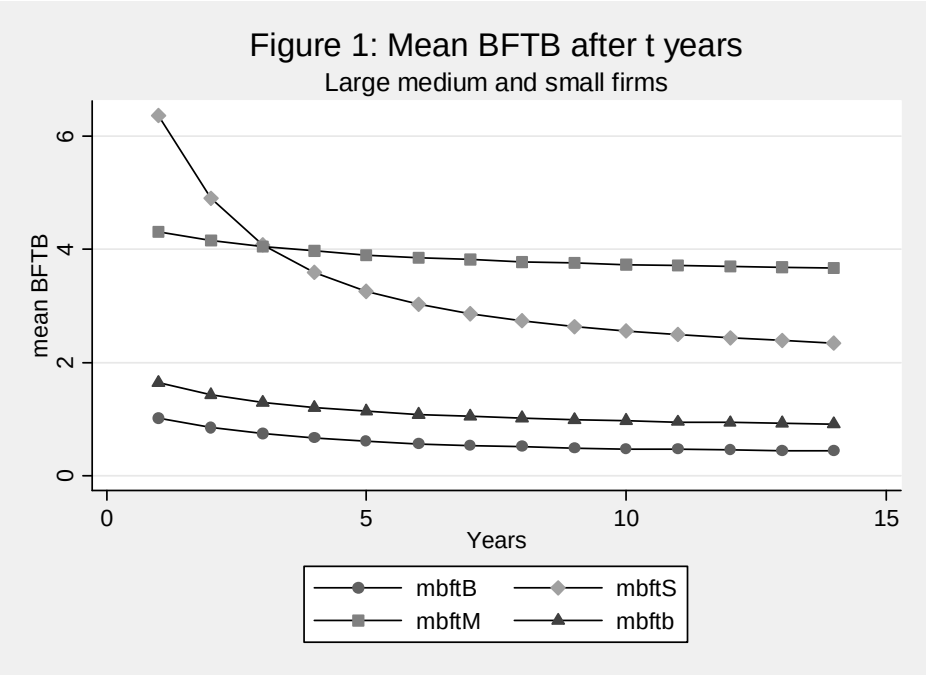
The BFTB is given by the ratio of equations (16), summed over all firms in our sample that received the tax credits and (17) i.e. $\sum_{t=1}^{\infty} (\tilde{R}_{it} - R_{it})/(1+r)^{t-1}$ and $\sum_{t=1}^{\infty} (\tilde{W}_t - W_t)/(1+r)^{t-1}$. In other words, we compute the ratio of the decreases in R&D along the entire trajectories to the saving in government costs to support the WBSO along the whole trajectory, both appropriately discounted[18].

[INSERT TABLE 5 HERE]

The values of the parameters corresponding to equations (16) and (17) and the results of the computations are listed in Table 5. The infinite sums given by (16) and (17) converge to a new steady state rather quickly, after 15 periods the change between K_t and K_{t-1} is negligible. The ratio of (16) and (17) produces a BFTB of 0.90. It can be seen as a weighted sum of individual ratios of additional R&D and WBSO costs to the government.

In our computation of BFTB we use size-class specific short and long-run elasticity re-estimated in the model II. We use three size classes: small firms with fewer than 50 employees, medium-sized firms (50 to 250 employees) and large firms (250 and more employees). The BFTB trajectory for each size class is different. We plot these trajectories in Figure 1. In the figure mbftB indicates the trajectory for large firms, mbftM, for medium-sized firms, mbftS for small firms and mbftb the average of all firms.

[18] Because of the unbalanced nature of our sample, t0 is different for every firm. We take it to be the last year a firm is observed in the sample. All parameters that enter the computation of (16) and (17) are taken for that particular year for each firm.



The WBSO program has the largest impact in the first period, after which the effect of the tax incentive declines. The initial impact is the largest for the smallest firms (about 6.4) and the smallest for the largest firms (1.02) and is 1.6 on aggregate. After an initial spike the effect declines rapidly, and after a few periods converges to about 1.87 for the smallest firms, 3.5 for the medium-sized firms and 0.37 for the largest firms[19]. The rapid decline of BFTB is due to the level-based nature of WBSO. Firms can apply for the wage tax deductions based on their annual R&D wage bill, regardless of their past R&D effort. In each period the government has to pay WBSO on the basis of the level of R&D, i.e. the current incremental R&D and the sum of R&D increments of the past periods. Supporting the latter, which would be done anyway, is a dead-weight loss from the social planner's perspective. In contrast, with increment-based R&D tax incentive only the additional R&D would be supported. As a result, the denominator (17) grows at a higher rate than the numerator (16), until a new steady state is

[19] We have also computed a non-weighted sum of individual firm-specific BFTBs, which are given by the ratio of firm-specific extra R&D expenditures divided by the tax credits received by a firm, computed for each period. The results give a similar picture to the weighted BFTB approach. The mean value (after convergence) of such firm-specific BFTBs is 0.44 for the largest firms (S.D 0.14), 2.05 (SD 0.92) for the smallest firms and 3.85 (SD 1.42) for the medium sized firms. The median BFTB is close to the mean and is 1.4.

reached, which results in an overall BFTB smaller than 1[20]. The adjustment to a new steady state is faster for medium and larger-sized firms, reflected in higher estimated parameter λ.

These results of this experiment suggest that for all but the largest firms in our sample a hypothesis of full crowding out can be rejected and that the fiscal incentives program has been successful in stimulating firms' investment in R&D.

5. Conclusions

In this paper we have analyzed the effectiveness of the R&D fiscal incentive program (the so called WBSO program) in the Netherlands. We have estimated a dynamic factor-demand model based on a CES production function to measure the responsiveness of a firm's R&D capital accumulation to its user cost. We have estimated our econometric model on a firm-level sample covering 1996-2004. The richness of the dataset allowed us to construct firm-specific R&D user costs as a function of R&D tax incentives. We have used various model selection criteria to choose a model with an appropriate time lag with which adjustment to the policy changes takes place.

The results suggest that R&D is responsive to its user cost. We obtain a short-run elasticity of about 0.3 and a long-run elasticity of 0.7. According to our preferred specification the adjustment speed to the fiscal policy change is quite high and is achieved within 2-3 periods.

To evaluate whether the R&D incentives program is successful we have performed an experiment in which we have simulated the reduction in R&D in case of the suppression of the WBSO. By calculating the amount of the decrease in R&D in the absence of tax credits and the present and future costs of the WBSO program we have computed the so called "bang for the buck", given by the ratio

[20] As a quick check of the sensibility of this result we could do the following simple calculation. Suppose that in year t government introduces a WBSO scheme that on average lowers firms' R&D cost by 5% and that WBSO constitutes 5% of the R&D expenditures. If the long-run price elasticity is 0.7 (estimated in model II) then in the long run WBSO increases firms' R&D capital by 3.5% relative to the initial steady-state. A permanent increase in R&D expenditures (replacement investment) of 3.5% would be necessary to correspond to a 3.5% long-run increase in R&D stock because in the long run R&D stock is proportional to R&D flow. The long-run BFTB will then be 0.7, which is 3.5% extra R&D expenditures divided by 5% WBSO. In the short run R&D capital will increase by 1.4% (short-run elasticity of 0.38 x 5% WBSO). If we assume a depreciation rate of 15%, this means that in the first year after the introduction of WBSO the R&D expenditures will have to increase by 9.33% relative to the situation without WBSO. Starting from a steady state situation where the stock of R&D equals R&D expenditure divided by the depreciation rate, a change in the R&D stock of 1.4% corresponds to a change in R&D expenditure of 1.4/0.15 = 9.33%. This would give a short-run BFTB of 1.87. We thank Piet Donselaar for making this point. This calculation gives an approximate order of magnitude since WBSO disbursements are not a linear function of R&D expenditures.

of these two amounts. According to our results WBSO has the largest impact in the first period after which the effect of the tax incentives declines. We find that the effect is the largest for smallest firms and is smaller for the larger firms. After an initial shock, the impact of the tax incentives program gradually declines until a new steady state is reached. The BFTB decline is due to the level-based nature of WBSO, meaning that firms can apply for the wage tax deductions for the current year regardless of the their past R&D effort. As a result, the cost of WBSO to the government in our experiment grows faster than the incremental (additional) firm R&D that WBSO stimulates.

Our overall conclusion in this paper is that the program of R&D incentives in the Netherlands has been effective in reducing the user cost of R&D and therefore has been successful in stimulating firm R&D capital formation. Several other elements would have to be included to make the cost-benefit analysis of the tax incentive program more complete. In addition to possible external effects and side effects in the benefits of the tax program, we would also need to consider the administrative and implementation costs for the firms and the government. These costs are difficult to measure accurately.

Table 1 Variable constructions and descriptive statistics

Variable	Construction	Source	Mean	S. Dev.
R&D flow/stock	Own R&D expenditures divided by R&D stock at beginning of the period	CIS/R&D	0.24	0.42
User cost of R&D	see Appendix A	CIS/R&D/SN	0.26	0.06
Value added	in logarithm	PS	16.04	1.34
Industry sales	Mean industry sales (at 2-digit industrial classification) in logarithm	PS	17.84	0.95

Note: The descriptive statistics are sample means for the years 1996-2004

Table 2 Overview WBSO program parameters

Year	WBSO budget (in mln. Euro)	Length of the first bracket (in Euro)	% First bracket	% Second bracket	Ceiling (in mln. Euro)
1996	204	68067	40	12.05	4.5
1997	227	68067	40	12.5	6.8
1998	281	68067	40	17.5	6.8
1999	293	68067	40	13	6.8
2000	302	68067	40	13	6.8
2001	337	90756	40 or 60 (s)	13	7.9
2002	367	90756	40 or 70 (s)	13	7.9
2003	323	90756	40 or 60 (s)	13	7.9
2004	365	110000	40 or 60 (s)	14	7.9

Source: Ministry of Economic Affairs (2007); (s) stands for 'starters'

Table 3 Annual average user cost of R&D and its components (2615 observations)

Year	$P_R(r+\delta)$	WBSO Tax credit	B-index	User cost of R&D	User cost of R&D w/o WBSO tax credit
	(1)	(2)	(3)	(4)	(5)
2004	0.388	0.194	0.808	0.314	0.389
2003	0.364	0.187	0.815	0.298	0.366
2002	0.334	0.200	0.803	0.268	0.334
2001	0.309	0.216	0.791	0.245	0.312
2000	0.311	0.207	0.797	0.248	0.312
1999	0.306	0.200	0.806	0.246	0.308
1998	0.298	0.191	0.815	0.243	0.300
1997	0.308	0.173	0.833	0.258	0.310

Notes: The corporate income tax rate used in the construction of the user cost has decreased on average for the sampled firms from 36% to 29% between 1997 and 2004. B-index (column 3) is calculated as using expression (A4) in Appendix A; WBSO tax credit (column 2) is calculated using the expression in square brackets (times wage share) of A4. Column (4) is a product of column (1) and column (3). Column (5) is the product of column (1) and the sum of column (3) and column (2).

Table 4. Effects of WBSO, estimation of equation (12) and equation (14)

	Model I (Equation 12)				**Model II (Equation 14)**
	1	2	3	4	5
$R_{i,t-1}/K_{i,t-2}$					0.603*** (0.158)
$du_{i,t}$					
$-\sigma_0$	-0.284*** (0.083)	-0.271*** (0.101)	-0.502*** (0.192)	-0.573* (0.299)	-0.283*** (0.101)
$-\sigma_1$		-0.121*** (0.045)	-0.244** (0.096)	-0.334* (0.169)	
$-\sigma_2$			-0.144* (0.066)	-0.232* (0.120)	
$-\sigma_3$				-0.184 (0.097)	
LR price elasticity	-0.284*** (0.083)	-0.392*** (0.138)	-0.890** (0.333)	-1.323* (0.633)	-0.715*** (0.242)
$dv_{i,t}$					
ϕ_0	0.069** (0.029)	0.062** (0.028)	0.090** (0.040)	0.134** (0.060)	0.058* (0.033)
ϕ_1		0.052** (0.024)	0.076** (0.031)	0.134** (0.042)	
ϕ_2			0.003 (0.034)	0.079* (0.048)	
ϕ_3				0.198** (0.053)	
LR output elasticity	0.069** (0.029)	0.114** (0.040)	0.169 (0.068)	0.545** (0.125)	0.147* (0.062)
R^2	0.24	0.33	0.22	0.18	0.28
Sargan statistic (p-value)	0.07 (0.80)	3.32 (0.19)	0.28 (0.87)	0.20 (0.90)	0.48 (0.79)
White's statistic (p-value)	41.95 (0.98)	108.49 (0.12)	123.99 (0.74)	113.70 (0.20)	117.01 (0.45)
Log-likelihood	-1436.47	-260.82	-283.67	-272.40	-235.05
AIC	2890.93	545.63	597.35	680.99	502.10
Number of firms	841	549	402	248	402
Number of observations	2615	1742	1185	780	1185

Notes: Estimation period is 1996-2004.
*** indicates significance at 1%, ** at 5%, * at 10%.
Standard errors of the long-run elasticities are computed using the delta method.

Table 5 Parameters used to compute BFTB, infinite lag model

Parameter	$\sigma\mu$	λ	$\sigma\mu/(1-\lambda)$	δ	r	Δu	u	BFTB
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(9)
	-0.283	0.603	-0.715	0.15	0.03	0.062	0.242	0.9

Note: In columns (6) and (7) we report the sample mean value.

References

Baum, C., Schaffer, M., Stillman, S., 2007. Enhanced routines for instrumental variables/GMM estimation and testing. Working paper, forthcoming.

Bernstein, J., 1986. The effect of direct and indirect tax incentives on Canadian industrial R&D expenditures. Canadian Public Policy 12(3), 438-48.

Bloom, N., Griffith, R., Van Reenen, J., 2002. Do R&D tax credits work? Evidence from a panel of OECD countries 1979-1997. Journal of Public Economics 85, 1-31.

Brouwer, E., den Hertog, P., Poot, T., Segers, J., 2002. WBSO nader beschouwd. Onderzoek naar de effectiviteit van de WBSO, Opdracht van het Ministerie van Economische Zaken, DG Innovatie.

Bureau of Labor Statistics, 1989. The impact of research and development on productivity growth, US Department of Labor Bulletin No. 2331.

Central Bureau of Statistics, 2004. Kennis en Economie. CBS, Voorburg.

Chirinko, R., Fazzari, S.M., Meyer, A.P., 1999. How responsive is business capital formation to its user cost? An exploration with micro data. Journal of Public Economics 74, 53-80.

Cornet, M., Vroomen, B., 2005. Hoe effectief is extra stimulering van speur- en ontwikkelingswerk?, CPB document No. 103.

Cragg, J., Donald, S., 1993. Testing identifiably and specification in instrumental variables models. Economic Theory 9, 222-40.

Dagenais, M., Mohnen, P., Therrien, P., 2004. Les firmes canadiennes répondent-elles aux incitations fiscales à la recherche-développement? Actualité Économique 80(2/3), 175-206.

Duguet, E., 2004. Are R&D subsidies a substitute or complement to privately funded R&D? Evidence from France using propensity score methods for non experimental data. Revue d'Economie Politique 114(2), 263-92.

Fazzari, S., Hubbard, R., Petersen, R., 1988. Financing constraints and corporate investment. Brookings Papers on Economic Activity 1, 141-95

Hall, B., 1992. Investment in Research and Development at the firm level: Does the source of financing matter? NBER Discussion Paper 4096.

Hall, B., 2003. R&D tax policy during the eighties: success or failure? Tax Policy and the Economy 7, 1-36.

Hall, B., Van Reenen, J., 2000. How effective are fiscal incentives for R&D? A review of the evidence. Research Policy 29, 449-469.

Hao, K., Jaffe, A., 1993. Effect of liquidity on firm's R&D spending. Economics of Innovation and New Technology 2, 275-82.

Harhoff, D., 1998. Are there financing constraints for R&D and investment in German manufacturing firms? Annales d'Economie et de Statistique 49/50, 421-56.

Himmelberg, C., Petersen, B., 1994. R&D and internal finance: a panel study of small firms in high-tech industries. Review of Economics and Statistics 76(1), 38-51.

Hines, J., 1993. On the sensitivity of R&D to delicate tax changes: the behavior of U.S. multinationals in the 1980s. In: Giovannini A., Hubbard, R. and Slemrod, J. (Eds.). Studies in International Taxation. Chicago: University of Chicago Press, 149-94.

Jaumotte, F., Pain, N., 2005. From Ideas to Development: The Determinants of R&D and Patenting. OECD Economics Department Working Paper No. 457.

Klette, T., J., Griliches, Z., 1996. The inconsistency of common scale estimators when output prices are unobserved and endogenous. Journal of Applied Econometrics 11, 343–361.

Mairesse, J., Mulkay, B., 2003. R&D et coût du capital: une évaluation du crédit d'impôt recherche en France, mimeo.

Mamuneas, T., Nadiri, M.I., 1996. Public R&D policies and cost of behavior of the US manufacturing industries. Journal of Public Economics 63, 57-81.

Ministry of Economic Affairs, 2007. Evaluatierapport WBSO 2001-2005: Effecten, doelgroepbereik en uitvoering (http://www.minez.nl/content.jsp?objectid=151570&rid=141650).

Nickell, S., 1981. Biases in dynamic models with fixed effects. Econometrica 49, 1417-1426.

McFetridge, D.G., Warda, J.P., 1983. Canadian R&D Incentives: Their Adequacy and Impact, Canadian Tax Paper No. 70. Toronto: Canadian Tax Foundation.

Pagan, A.R., Hall D., 1983. Diagnostic tests as residual analysis, Econometric Reviews 2(2), 159-218.

Stock, J., Watson M., 2003. Introduction to Econometrics. Boston: Addison-Wesley.

Stock, J., Yogo, M., 2005. Testing for weak instruments in linear iv regression. In Andrews D., Stock, J. (Eds.). Identification and inference for econometric models: essays in honor of Thomas Rothenberg. Cambridge: Cambridge University Press, 80-108.

Van Leeuwen, G., Klomp, L., 2006. On the contribution of innovation to multi-factor productivity. Economics of Innovation and New Technology 15(4/5), 367-90.

Appendix A: Measurement of the user cost of R&D in the Netherlands

The user cost of R&D measures how much it costs a firm to hold a unit of R&D stock of knowledge. It corresponds to the price for this unit of knowledge if there was a rental market for knowledge. The user cost of R&D is derived from the equality between the net (after-tax) "rental" cost of a unit of R&D and the net (of tax incentives) purchase price of that same unit, given by the following equality:

$$N_i.P_R(t) = \int_t^{\infty} e^{-[r+\pi](s-t)} e^{-\delta(s-t)} (1-\tau) u_{Ri}(s) ds \qquad \text{(A1)}$$

where $P_R(t)$ is the R&D deflator (an index of the purchase price of the various R&D components (labor, buildings, equipment, and material)[21], N_i is the percentage of the purchase price that remains after deduction of all R&D tax incentives (if there were no tax incentives, N_i=1), r is the real interest rate, π is the inflation rate in the R&D price, δ is the depreciation rate of the stock of knowledge[22], τ is the corporate income tax rate, and u_{Ri} is the user or rental cost of R&D. Equation (1) states that the net of tax incentives purchase price of one unit of R&D knowledge should be equal to the present value of all future, tax deductible, rental costs that would have to be paid for the non-obsolete part of the initial unit of knowledge. If it is cheaper to invest in knowledge rather than buying it from others, then firms would rather invest until either the borrowing price falls or the purchase price rises to re-establish the equilibrium denoted by equation (A1). Equivalently, we could consider the arbitrage condition to be one of equality between the net purchase price and the present value of the rental returns that can be derived over time from the non-depreciated portions of that same unit of R&D. If the price is cheaper than the returns, a firm invests in R&D; otherwise a firm rents the R&D knowledge.

By differentiating both sides of this expression, we get

$$\begin{aligned} N_i.P_R(t)\pi &= -(1-\tau)u_{Ri}(t) + (r+\pi+\delta)\int_t^{\infty} e^{-[r+\pi](s-t)} e^{-\delta(s-t)} (1-\tau) u_{Ri}(s) ds \\ &= -(1-\tau)u_{Ri}(t) + (r+\pi+\delta)B_i.P_R(t) \end{aligned} \qquad \text{(A2)}$$

[21] The R&D deflator is constructed as $PR = 0.5 p_{GDP} + 0.5 p_{R\&D,L}$, where p_{GDP} is the GDP deflator and $p_{R\&D,L}$ is the R&D wage index. The idea of using a 50/50 weighted average of the GDP deflator and the R&D wage index was suggested by Jaffe and Griliches and has come to be known as the Jaffe-Griliches R&D deflator (see Bureau of Labor Statistics (1989)).

[22] The R&D depreciation rate is assumed to be equal to 15%. We also experimented with rates ranging from 10% to 25%. 25% corresponds to a depreciation rate consistent with patent decays (see Pakes and Schankerman (1984)). These changes do not lead to statistically different outcomes in our models. Insensitivity of R&D rates of return to assumed R&D depreciation rates are also reported by Hall and Mairesse (1995).

which can then be solved for the user cost[23], deleting the time subscript to simplify the notation:

$$u_{Ri} = \frac{P_R(r+\delta)}{1-\tau} N_i = P_R(r+\delta).B_i \cdot \qquad \text{(A3)}$$

B_i is also known in the literature as the B-index. The latter, introduced by McFetridge and Warda (1983), is defined as the ratio of the net cost of a euro spent on R&D, after all quantifiable tax incentives have been accounted for, to the net income from one euro of revenue. If for instance a firm spends one euro on R&D and it can expense it, and the corporate tax rate is 50%, then one euro of R&D costs effectively 50 eurocent, hence one euro of return before tax is equivalent to 50 eurocent after tax. The B-index in this case is equal to 1.

Given the R&D tax incentive structure in the Netherlands, the B-index looks as follows, ignoring for the sake of clarity the t subscripts[24]:

$$B_i = \frac{1}{1-\tau}\left\{\begin{array}{l} 1-(1-\tau)w_i^L \\ D_{1i}\left[\begin{array}{l} [\omega_1^1(1-D_{2i})+\omega_2^1 D_{2i}]\min\left(\frac{R_L^1}{w_i^L R_i},1\right)+1_{R_L^1<w_i^L R_i}[\omega_1^2(1-D_{2i})+\omega_2^2 D_{2i}] \\ \min\left(1-\frac{R_L^1}{w_i^L R_i}, \frac{(R_L^2-[\omega_1^1(1-D_{2i})+\omega_2^1 D_{2i}]R_L^1)/[\omega_1^2(1-D_{2i})+\omega_2^2 D_{2i}]}{w_i^L R_i}\right) \end{array}\right] \\ -\tau w_i^B z^B - \tau w_i^E z^E - \tau w_i^O - \tau w_i^L \end{array}\right\} \qquad \text{(A4)}$$

where

w_i^L = % of labor costs in total R&D

w_i^B = % of land and building expenses in total R&D

w_i^E = % of machinery and equipment expenses in total R&D

w_i^O = % of current R&D expenses other than labor

[23] The expression for the user cost of R&D can also be derived from an inter-temporal maximization problem with financing and R&D decisions. The exact expression is then dependent on the assumptions made about time lags, adjustment costs, expectations etc. For an example of such a derivation, see Mairesse and Mulkay (2003). At this point we think it is premature to derive the user cost for a fully specified dynamic model.

[24] The interest rate in the user cost of R&D expression could be corrected for risk. The returns from riskier projects would be discounted more. However, in practice it is difficult to measure this risk factor. Since the risk element is probably case specific, it will be partially eliminated in panel data by correcting for an individual effect (only partly, because the risk premium in the user cost of capital expression does not enter linearly in the estimating equation).

$D_{1i} = 1$ if R&D performer is eligible and willing to use WBSO

$D_{2i} = 1$ if the "starters facility regulation" can be applied (see Cornet and Vroomen (2005) for details)

ω_1^1 : first bracket WBSO rate for firms eligible to WBSO but not to the "starters facility regulation"
ω_2^1 : first bracket WBSO rate for firms eligible to the starter's facility regulation
ω_1^2 : second bracket WBSO rate for firms eligible to WBSO but not to the starter's facility regulation
ω_2^2 : second bracket WBSO rate for firms eligible to the starters facility regulation, (N.B. $\omega_1^2 = \omega_2^2$).
R_L^1 : first bracket ceiling (expressed in terms of deductible R&D labor costs) deflated by the R&D deflator. For example, in 2001, $p_R R_L^1$ = 90.756 €.
R_L^2 : second bracket ceiling (expressed in terms of reduced labor taxes) deflated by the R&D deflator. For example, in 2001, $p_R R_L^2$ = 7.9 million €.[25]

z_B = present value of all future depreciation allowances due to land and buildings, where ϕ^B is the rate of capital consumption allowance for land and buildings (5%). The exact expression for z_B depends on the depreciation schedule (straight-line or geometric). Straight-line depreciation seems to be the norm in the Netherlands according to //ww.inzakegaan.nl/fiscus/investeringsaftrek.html. Hence,

$$z_B = \phi_B + \frac{\varphi_B}{1+r+\pi} + \ldots + \frac{\varphi_B}{(1+r+\pi)^{T-1}} = \frac{\phi_B}{1-(1/1+r+\pi))} - \frac{\phi_B/(1+r+\pi)^T}{1-(1/1+r+\pi))} =$$
$$\frac{\varphi_B}{r+\pi}(1+r+\pi)(1-\frac{1}{(1+r+\pi)^T})$$

where π is the inflation rate in the R&D deflator and T is the finite lifetime of the capital item under straight-line depreciation[26].

z_E = present value of all depreciation allowances due to machines and computers, where ϕ^E is the rate of capital consumption allowance for machines and computers ranging from 10% to 33%. We use the straight-line depreciation schedule and we take an average rate of 20% for all firms.

---

[25] We express the ceilings in real terms, because R&D is expressed in base-year prices. There is a slight problem of deflation here, in so far as the WBSO concerns only labor R&D costs which ought to be deflated by the wage index of R&D costs instead of the general R&D deflator.

[26] The interest rate in the user cost of R&D expression can be tax deductible if the R&D is financed by borrowed funds. But most R&D is financed by retained earnings and the opportunity cost from retained earnings is not tax deductible. In any case information on the source of finance (retained earnings versus borrowings from banks or issuing shares) is only available at the company level and not at the business unit level at which we are working.

The term in curly brackets in (A4) reads as follows. In the presence of R&D tax incentives it costs less than 1 € to purchase the equivalent of one € of R&D knowledge. The 1 corresponds to a 1€ of expenditures in R&D. Get deducted from this one € various amounts, actually fractions of one €, relating respectively to WBSO deductions from labor taxes, building and equipment amortizations, and current costs deductions, corresponding to labor and other costs. Let us examine these expressions one by one.

The second term in square brackets corresponds to the WBSO. To the extent that R&D is labor cost, and depending on the amount of R&D that is performed, and on whether the "starters facility regulation" can be invoked, a percentage of the R&D labor costs can be deducted from social security contributions. If the amount of R&D labor falls below level R_L^1, the first bracket rate can be used, above that level the second rate is applicable up to a total permissible deduction of R_L^2. In case of start-up firms, the first bracket rate is a bit more generous. Finally, the WBSO deductions are themselves taxed, hence only the non-taxed part represents a true deduction from the initial purchase price. For illustration, suppose w^L=0.80, R&D is eligible for WBSO ($D_1 = 1$), it occurs at an R&D level below the first bracket ceiling, R_L^1 for a non-starter ($D_2 = 0$), where the WBSO rate ω_1^1=0.40, and the corporate income tax rate is 0.40. Then thanks to the WBSO the average R&D investment of one € benefits from a WBSO-driven tax incentive of 0.192.

The next two terms in curly brackets in (A4) correspond to what can be recovered from the purchase of one Euro of R&D because of amortization, either in terms of land and buildings (B) or in terms of machinery and equipment (E). The present value of all future depreciation deductions can be deducted from the effective purchase price. The amount then depends on the allowable depreciation deductions and the schedule of those reductions (e.g. straight-line or geometric) and the corresponding rates. For the sake of illustration, suppose w^B=0.05 and w^E=0.05 and straight-line depreciation for both (B) and (E), a capital consumption allowance of ϕ^B=0.05 for buildings and of ϕ^E=0.20 for machinery and equipment, and a nominal interest rate plus risk premium of 0.20. The respective lifetimes are thus 20 years for buildings and 5 years for machinery and equipment. The magnitude of $\tau w^E z^E$ and $\tau w^B z^B$ are then respectively 0.014 and 0.006.

To the extent that this euro corresponds to current costs (labor or other) it can be immediately expensed (i.e. deducted from taxable profits). The income tax so recoverable can be deducted from the purchase price. This explains the last two terms of the expression in curly brackets in equation (4). For

illustration, suppose that w^O =0.10. The last two terms in the curly brackets of (4) are then 0.32 and 0.02 respectively. Hence in our example, the net cost of 1 Euro of R&D is equal to 1-0.192-0.014-0.006-0.32-0.02=0.448. The B-index would then be equal to 0.448/0.60 =0.745.

It could be argued that what matters for a marginal investment for firms above the first WBSO ceiling is the second bracket WBSO rate. Any increase in the first bracket rate would be considered as windfall profit and not affect the marginal R&D decision: we believe that it makes sense to consider that this windfall profit gets reinvested in R&D (as it appears as WBSO money). If we assume that only the marginal WBSO rates matter, then the B-index would be:

$$B_i = \frac{1}{1-\tau}.\{1-(1-\tau)\ w_i^L D_{1i}[(\omega_1^1(1-D_{2i})+\omega_2^1 D_{2i})D_{1i}^1 + (\omega_1^2 D_{1i}^2(1-D_{2i})+\omega_2^2 D_{2i}^2 D_{2i})] - \tau w_i^B z^B - \tau w_i^E z^E - \tau w_i{}^O - \tau w_i{}^L\} \quad \text{(A5)}$$

where

$D_{1i}^1 = 1$ if $w_i{}^L R_i \le R_L^1$, i.e. R&D labor costs are below the first bracket ceiling.

$D_{1i}^2 = 1$ if $R_L^1 < w_i{}^L R_i \le (R_L^2 - \omega_1^1.R_L^1)/\omega_1^2$, i.e. if R&D is between the first bracket and the second bracket ceiling for cases, where D_{2i} is not applicable.

$D_{2i}^2 = 1$ if $R_L^1 < w_i{}^L R_i \le (R_L^2 - \omega_2^1.R_L^1)/\omega_2^2$ (N.B. $\omega_1^2 = \omega_2^2$), i.e. if R&D is between the first bracket and the second bracket ceiling for cases, where D_{2i} is applicable for new starters.

Appendix B Comparison of the present study with the study for the Ministry of Economic Affairs (2007)

In the study for the Ministry of Economic Affairs (2007) two methods are proposed to estimate the effect of WBSO on private R&D and the effectiveness of the WBSO. The direct method follows the early study by Brouwer *et al.* (2002). It consists in regressing the labor costs of R&D or the total R&D expenditures on one and two year lagged values of WBSO disbursements. The indirect method is the one adopted in the present study.

The direct approach yields a marginal effect on R&D labor expenditures of one-year lagged WBSO disbursements that is valued at 1.27 (the two year lagged WBSO is not significant). If we convert it to a marginal effect of total R&D expenditures using an average R&D labor share, we obtain a marginal point estimate of 1.72. The indirect approach used in the Ministry of Economic Affairs (2007) study is based on a common elasticity of substitution between the individual prices and the overall price index, instead of a common elasticity of substitution between individual prices and industry-wide prices (equation (5)). In the present study we also explore a geometric distributed lag model instead of a finite distributed lag model, and we use size-specific estimates to compute the bang for the buck (BFTB). The estimated price elasticities of R&D reported here are not significantly different from those reported in the previous specification. Whereas the corresponding BFTB's are very similar in the short run, they differ in the long run. The present calculations yield a BFTB of 0.90 against 0.51 previously.

The direct approach does not require the calculation of a stock of R&D, and therefore can be based on a much larger sample of observations (10 681 compared to 1 185 in our preferred specification). It is, however, less appealing from a theoretical point of view, as it relies not on a price measure (which itself is not totally exogenous) but on the product of past R&D tax incentives and R&D expenditures, where the tax break is automatically determined by the amount of past R&D expenditures.