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How effective are level-based R&D tax credits? Evidence from the Netherlands

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Abstract

This paper examines the impact of the R&D fiscal incentive program on R&D by Dutch firms. Taking a factor-demand approach we measure the elasticity of firm R&D capital accumulation to its user cost. Econometric models are estimated using a rich unbalanced panel of firm data covering the period 1996-2004 with firm-specific R&D user costs varying with tax incentives. Using the estimated user cost elasticity, we perform a cost-benefit analysis of the R&D incentive program. We find some evidence of additionality suggesting that the level-based program of R&D incentives in the Netherlands is effective in stimulating firms' investment in R&D. However, the hypothesis of crowding out can be rejected only for small firms. The analysis also indicates that the level-based nature of the fiscal incentive scheme leads to a substantial social dead-weight loss.

Keywords: R&D tax credits; panel data; crowding out; user-cost elasticity

JEL Classification: O32, O38, H25, H50, C23

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I. Introduction

Many governments rely on fiscal incentives to lower the user cost of R&D and thereby stimulate business investment in research and development. The market failures due to R&D externalities and asymmetric information between lenders and borrowers for the financing of R&D projects are often cited to justify the existence of such government programs, which often involve substantial budgets (OECD, 2007). The effectiveness of R&D fiscal incentives programs, however, continues to be the object of intense debate among economists.

We know from economic theory that investment in R&D can be modeled in the same way as investment in physical capital, and that therefore the user cost of R&D is a primary determinant of a firm's decision to invest in research and development. The elasticity of R&D with respect to its price is the main parameter of interest when assessing the effectiveness of such programs. Few studies have estimated this elasticity on firm-level data.¹ Notable exceptions are early contributions by Hall (1993) on the effectiveness of US Research and Experimental Credit; Bernstein (1986) on R&D support program in Canada and a more recent study by Mairesse and Mulkey (2004) on French data.

In this paper we take a fresh look at the sensitivity of the R&D capital accumulation to the user cost and assess the additionality of the R&D tax incentive program, such as the WBSO Act². The focus of previous received contributions was primarily on estimating precisely the magnitude of the elasticity of R&D to its price. The emphasis in this paper is on the cost-benefit trade-off of the government support of R&D. Fiscal programs, especially when they are level-based, are costly and in contrast to the previous literature that merely acknowledged the possibility of some significant waste from the social planner perspective (e.g. Russo, 2004), we actually attempt to quantify the magnitude of the dead-weight-loss due to present and future R&D and tax receipts forgone.

¹ Several studies produced evidence using the user cost, or structural, approach in the estimation of the effectiveness of R&D tax incentives on industry data (e.g. Mamuneas, Nadiri, 1996; Bloom, Griffith, van Reenen, 2002) or aggregate data (e.g. Falk, 2006; Jaumotte and Pain, 2005). A critical discussion of the state of the art in this literature is provided by Hall and van Reenen (2000). Many other studies evaluate the effects of tax incentives using counterfactuals, i.e. matching estimators, difference-in-difference estimators or regression discontinuity designs (see Czarnitzki, Hanel and Rosa, 2004, Hægeland and Møen, 2007, Duguet, 2007, Corchuelo and Martínez-Ros, 2009). The quasi-experimental approach does not allow to perform policy experiments unlike the user-cost based structural model.

² 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.

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3 The model considers each firm's demand for R&D capital, among other things, as a negative
4 function of its price (user cost). Government lowers the price of R&D by implementing tax
5 deductions on R&D labor, which triggers a partial adjustment process to a higher desired
6 R&D stock. Our dynamic factor demand model accounts for this partial adjustment
7 mechanism and is based on a CES technology (cf. Chirinko, Fazzari, Meyer, 1999; Mairesse
8 and Mulkay, 2004; Hall and van Reenen, 2000). We estimate the model using a firm-level
9 unbalanced panel dataset covering 1996-2004, constructed from the annual R&D surveys,
10 production statistics from the Central Bureau of Statistics and R&D tax incentives data. The
11 richness of the merged dataset allows us to construct R&D price indexes and year- as well as
12 firm-specific R&D user costs as a function of R&D tax incentives. Our firm-specific data
13 allow a good measurement of the user cost by providing sufficient variation in the indexes in
14 both the cross-section and time dimensions to improve the estimation of the effects of the
15 R&D fiscal incentives program. To account for the endogeneity of the user cost of R&D we
16 apply a generalized instrumental variables method to estimate a significant short-run elasticity
17 of -0.4 and a long-run elasticity of -0.8 of firm R&D capital formation to its user cost.
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20 We apply the estimated user cost elasticity of R&D capital stock to assess the
21 effectiveness of the fiscal incentives program by comparing the additional R&D spurred by
22 the fiscal incentives program to the cost for the government of supporting the R&D with the
23 tax scheme. Our measure of the so-called bang-for-the-buck differs from the measures
24 adopted in most other papers (Czarnitzki et al., 2004; Parsons and Phillips, 2007) in that we
25 compare the costs and benefits incurred until the firm reaches a new steady state in its R&D
26 capital stock. When the adjustment to the new optimal stock is spread out over time, it is
27 appropriate to compare the costs and benefits in a dynamic perspective allowing for a rate of
28 time preference.
29

30 We find evidence that the program of R&D incentives in the Netherlands has been
31 effective in stimulating firms' investment in R&D. However, the hypothesis of crowding out
32 can be rejected only for small firms. The results of our simulations also indicate that the level-
33 based nature of the fiscal incentive scheme leads to the government supporting R&D which
34 firms would do even without the tax incentives, resulting in a substantial deadweight loss (as
35 much as 85% of the total revenue loss) from the social planner's perspective.
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38 The rest of the paper is organized as follows. Section 2 lays out our modeling
39 approach. Section 3 describes the way we have assembled our data set and explains how we
40 have constructed the variables used in the empirical analysis. Section 4 presents our empirical
41 results. We discuss several regression specifications, leading to our preferred specification.
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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. Section 6 concludes.

II. Empirical model

We derive a modeling framework that allows estimating the elasticity of firm R&D capital accumulation to its user cost. We start from a CES approximation to the true production function for firm i at time t (following Chirinko et al., 1999; Hall and van Reenen, 2000; Mairesse and Mulkey, 2004):

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

where $Q_{i,t}$ is the output, $K_{i,t}$ is the end-of-period R&D stock, $X_{i,t}$ represents the other inputs, and γ (a scale factor), β (the distribution parameter), and 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 the R&D stock and the other inputs and is given by $\sigma = 1/(1+\rho) \geq 0$. If we assume away any adjustment lags we can derive the profit maximizing long-term R&D stock as a function of output and the user cost of R&D $u_{i,t}^R$ divided by the firm's output price $p_{i,t}^Q$ (where small letters denote logarithmic transformations):

$$k_{i,t}^* = a + (\sigma + (1-\sigma)/\nu)q_{i,t} - \sigma(u_{i,t}^R - p_{i,t}^Q). \quad (2)$$

The volume of output and the output price are difficult to measure at the micro level. To eliminate the need to measure individual output prices, we follow Klette and Griliches (1996) and introduce an output demand equation with constant price elasticity given by

$$Q_{i,t} = Q_{I,t} \left(\frac{P_{i,t}^Q}{P_{I,t}} \right)^{-\varepsilon} \quad (3)$$

where $Q_{I,t}$ is the industry demand and $P_{I,t}$ the industry price in period t , and ε is the price elasticity in absolute value ($\varepsilon > 0$).

Inserting (2) into (3) yields

$$k_{i,t}^* = a + \phi v_{i,t} - \sigma(u_{i,t}^R - p_{I,t}) + \gamma q_{I,t} \quad (4)$$

where $v_{i,t}$ is the firm's nominal output deflated by the industry price index, $\phi = \sigma + \zeta(1 - \sigma)/\nu$, and $\gamma = (1 - \zeta)(1 - \sigma)/\nu$.³

To introduce a parsimonious specification that allows distinguishing between 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. A partial adjustment mechanism could be appended to equation (4) resulting in the addition of a lagged dependent variable term. The error term could be decomposed into an individual and an idiosyncratic effect. Bloom, Griffith and van Reenen (2002) have estimated such a specification, which is in terms of levels of R&D stocks.

An alternative approach would be to estimate an investment equation of R&D. Investment is composed of a replacement investment ($R_{i,t}^r$) and a net investment ($R_{i,t}^n$). The former is proportional to the R&D stock at the beginning of the period: $R_{i,t}^r = \delta K_{i,t-1}$. The latter represents the change in the R&D stock: $R_{i,t}^n = K_{i,t} - K_{i,t-1}$. Hence we can write

$$\frac{R_{i,t}}{K_{i,t-1}} = \frac{R_{i,t}^r + R_{i,t}^n}{K_{i,t-1}} = \delta + \frac{\Delta K_{i,t}}{K_{i,t-1}} = \delta + \Delta k_{i,t}. \quad (5)$$

We approximate the discrete growth rate in the R&D stock by a log difference and assume that the growth rate in the R&D stock follows a partial adjustment mechanism, which could be formalized by an adjustment cost model (Chirinko et al., 1999; Nadiri and Rosen, 1969),

³ The industry output disappears from equation (4) when either $\sigma = 1$ (Cobb-Douglas technology) or $\zeta = 1$ (perfect competition). Parameter ϕ equals 1 if either $\sigma = 1$ or $\zeta = 1$ and $\nu = 1$ (constant returns to scale).

$$k_{i,t} - k_{i,t-1} = \lambda(k_{i,t}^* - k_{i,t-1}) \quad (6)$$

Equation (6) can after substitutions be rewritten as

$$k_{i,t} - k_{i,t-1} = \lambda(k_{i,t}^* - k_{i,t-1}^*) + (1-\lambda)\lambda(k_{i,t-1}^* - k_{i,t-2}^*) + (1-\lambda)^2\lambda(k_{i,t-2}^* - k_{i,t-3}^*) + \dots \quad (7)$$

Changes in the R&D stock are therefore expressed as a weighted sum of the changes in the desired R&D stocks in the past. Equation (5) can then be rewritten as

$$\frac{R_{i,t}}{K_{i,t-1}} = \delta + \phi \sum_{h=0}^{\infty} \mu_h \Delta v_{i,t-h} - \sigma \sum_{h=0}^{\infty} \mu_h (\Delta u_{i,t-h}^R - \Delta p_{i,t-h}) + \gamma \sum_{h=0}^{\infty} \mu_h \Delta q_{i,t-h} + \varepsilon_{i,t} \quad (8)$$

where μ_h follow a Koyck scheme of exponentially declining coefficients $\mu_h = \lambda(1-\lambda)^h$ with $h=0,1, \dots$, and $\lambda < 1$. We have appended a random error term in (8) to account for random unobserved disturbances. Any individual effect present in (4) is removed by the first-differencing in (7).

Equation (8) can be simplified as

$$\begin{aligned} \frac{R_{i,t}}{K_{i,t-1}} &= \delta + \phi \sum_{h=0}^{\infty} \mu_h L^h \Delta v_{i,t} - \sigma \sum_{h=0}^{\infty} \mu_h L^h (\Delta u_{i,t}^R - \Delta p_{i,t}) + \gamma \sum_{h=0}^{\infty} \mu_h L^h \Delta q_{i,t} + \varepsilon_{i,t} \\ &= \delta + \phi \frac{\lambda \Delta v_{i,t}}{I - (1-\lambda)L} - \sigma \frac{\lambda (\Delta u_{i,t}^R - \Delta p_{i,t})}{I - (1-\lambda)L} + \gamma \frac{\lambda \Delta q_{i,t}}{I - (1-\lambda)L} + \varepsilon_{i,t} \\ &= \lambda \delta + (1-\lambda) \frac{R_{i,t-1}}{K_{i,t-2}} + \phi \lambda \Delta v_{i,t} - \sigma \lambda (\Delta u_{i,t}^R - \Delta p_{i,t}) + \gamma \lambda \Delta q_{i,t} + \varepsilon_{i,t} - (1-\lambda) \varepsilon_{i,t-1}. \end{aligned} \quad (9)$$

The short-run elasticity of R&D stock with respect to the user cost of R&D is given by $-\sigma\lambda$.

The long-run elasticity is given by $-\sigma$.

A third approach would be to assume an autoregressive distributed lag (ADL) specification for the R&D stock and to express the resulting equation in an error-correction (EC) form. This model has been adopted by Jaumotte and Pain (2005) and Mairesse and Mulkey (2004). Instead of equation (4) we have

$$k_{i,t} = \xi_1 k_{i,t-1} + \phi_0 v_{i,t} + \phi_1 v_{i,t-1} - \sigma_0 (u_{i,t}^R - p_{i,t}) - \sigma_1 (u_{i,t-1}^R - p_{i,t-1}) + \gamma_0 q_{i,t} + \gamma_1 q_{i,t-1} + \alpha_i + \eta_{i,t} \quad (10)$$

where $\xi_1 < 1$, α_i is the individual effect and η_{it} the idiosyncratic random effect. After rewriting (10) and combining it with (5) an ECM(1, 1) specification is obtained:

$$\frac{R_{i,t}}{K_{i,t-1}} = \delta + (\xi_1 - 1) \left[k_{i,t-1} - \frac{(\phi_0 + \phi_1)}{(1 - \xi_1)} v_{i,t-1} + \frac{(\sigma_0 + \sigma_1)}{(1 - \xi_1)} (u_{i,t-1}^R - p_{i,t-1}) - \frac{\gamma_0 + \gamma_1}{(1 - \xi_1)} q_{i,t-1} \right] + \phi_0 \Delta v_{i,t} - \sigma_0 \Delta (u_{i,t}^R - p_{i,t}) + \gamma_0 \Delta q_{i,t} + \alpha_i + \varepsilon_{i,t}. \quad (11)$$

The ECM(1,1) model gives us directly the short-run and long-run elasticities⁴. The short-run elasticity of R&D stock with respect to the user cost of R&D is given by $-\sigma_0$. The long-run elasticity is given by $-\frac{(\sigma_0 + \sigma_1)}{(1 - \xi_1)}$. This specification presents a somewhat more flexible adjustment mechanism at the price of three additional parameters to be estimated. It has also the advantage compared to (9) to include regressors in levels instead of only first differences. To the extent that these variables are persistent, taking first differences magnifies their noise component and thereby the errors in variable problem and the weak instrument problem. We shall nevertheless estimate all three specifications to check the robustness of our estimates.

III. Data and descriptive statistics

Data sample

The empirical analysis makes use of the Dutch Central Bureau of Statistic's annual CIS and R&D surveys in combination with production statistics. The R&D surveys contain information on firms' R&D expenditures and their breakdown by type, and the production statistics database contains information on output, employment and output deflators. These data sources and the process of merging them are explained in detail in Lokshin and Mohnen (2010). We estimate the model on an unbalanced panel of annual firm observations between 1996 and 2004.

⁴ It is possible to increase the number of lags and to test for an ECM(2,2) or ECM(3,3) specification, as estimated for example by Mairesse and Mulkey (2004). Compared to their study we have a relatively short time dimension and therefore we opt for an ECM(1,1) specification.

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5 Table 1 lists the main parameters of the WBSO program for our sample period. For example,
6 in the year 2004, there were two brackets: firms could deduct 42% of their R&D labor cost on
7 the first 110 thousand Euros in firm R&D wage expenditure, followed by a 14% deduction
8 rate on the remaining amount below the ceiling, which was set at 7.9 million Euros. There
9 have been a couple of changes over time in the length of the two brackets and the
10 corresponding rates of R&D wage cost deductions. For example, in 2001 the length of the
11 first bracket was extended from € 68,067 to € 90,756 and in the same year a higher additional
12 first-bracket tax credit for starters (60% as opposed to 40% for the rest) was introduced.
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25 After cleaning the data, we are left with the following distribution of our sample across size
26 classes.⁵ The middle size group (50 to 200 employees) represents around 59% of the total
27 number of firms. The largest firms (over 200 employees) are somewhat over-represented in
28 our sample. The smallest size group (fewer than 10 employees) is under-represented due to
29 the absence of innovation and R&D survey data from CBS over the whole period for firms
30 with less than 10 employees. In the end, firms in our dataset account on average, across all
31 years, for 15% of total WBSO expenditures and almost 25% of all R&D performed in the
32 Netherlands.
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40 *Variables*

41 The dependent variable in specifications (9) and (11) is the firm real R&D expenditures $R_{i,t}$
42 divided by its R&D stock in the previous period $K_{i,t-1}$. The main explanatory variables are
43 the user cost of R&D, value added and the industry output, in first differences in (9) and in
44 first differences and in levels in (11). We used the Fisher test as developed by Maddala and
45 Wu (1999) to check the stationarity of variables. The null hypothesis of unit root is rejected
46 for each of the variables. Table 2 provides descriptive statistics on the variables used in the
47 estimation.
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58 ⁵ We selected only those firms that perform R&D on a continuous basis, the so-called continuous
59 R&D performers, because in odd years CBS only collects data for continuous R&D performers. We
60 also selected only those firms that have a positive R&D in the 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.

[INSERT TABLE 2 HERE]

To construct the user cost of R&D, we use the information about the R&D cost composition, provided by CBS. The construction of the user cost is explained in detail in Lokshin and Mohnen (2010). Tax incentives are due to the WBSO program (see table 1) and the full or partial deductibility of R&D expenses. Table 3 shows the variation over time of the average user cost of R&D with and without R&D tax incentives for all the firms in our sample.

[INSERT TABLE 3 HERE]

The user cost in the absence of R&D tax incentives increased by 26% between 1997 and 2004. In the presence of R&D tax incentives it increased from 0.258 to 0.314, i.e. by 22% between 1997 and 2004. The increases in inflation and in the real interest rate have been tempered by the increase in R&D tax incentives. Variation in the user cost in the cross-sectional dimension comes from two sources. First, the variation is determined by whether a firm applies the standard or the preferential starter's rate. Second, the level of tax credit depends on the remittance rate that in turn depends on how high a firm's R&D wage bill is. The ensuing endogeneity of the user cost calls for good instruments. We discuss how we address this issue in the estimation section below.

IV. Econometric Results

The main results are reported in Table 4. The results from estimating a dynamic version of equation (4), the ECM(1,1) specification (11) and the geometrically lagged distribution partial adjustment model (9) are presented in columns (1) – (3) of Table 4. Because of the simultaneity between the user cost and the amount of R&D we have to instrument for the level or the change in the user cost of R&D in each specification. It is also reasonable to consider that the output of the firm is endogenous and needs to be instrumented. To follow Bloom et al. (2002) as closely as possible we estimate (4) using the within estimator instrumenting for the level of the real user cost of R&D, the level of output and the lagged dependent variable because of the presence of the individual effect. We use the following instruments: two- and three-period lagged levels of the R&D stock, the lagged level of real output, and the length of the first and second brackets of the WBSO tax incentive scheme, as

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3 well as the contemporaneous real R&D deflator, which varies at the sector level. The fiscal
4 incentives scheme's parameters are valid instruments because they are exogenous policy
5 decisions and yet reasonably correlated with the firm's user cost. The Shea partial R^2 in the
6 first-stage user-cost equation is 0.23 (F-test based on this measure is 39.62, p -value <0.01) and
7 0.09 for output. The Sargan test statistic is small (5.19 with a p -value of 0.16) and does not
8 reject the validity of the instruments. The estimated short-run user cost elasticity is -0.21 and
9 the long-run elasticity -0.56, both statistically significant.

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21 Column (2) of Table (4) lists the results from the ECM(1,1) specification. We estimate
22 equation (11) using the within estimator. The individual effects are treated as fixed as the
23 Hausman test rejects the null hypothesis of orthogonality of the individual effects and the
24 regressors ($\text{Chi}^2 = 112.28$, p -value 0.00). The change in the real user cost of R&D and the
25 change in output are likely to be correlated with the error term. Variables in levels are lagged
26 by one period and do not cause problems of endogeneity. The Hausman test rejects the null
27 hypothesis that the growth rate in the real user cost of R&D is exogenous ($\chi^2(1) = 8.11$) but
28 we cannot reject the exogeneity of contemporaneous change in output based on the
29 difference-in-Sargan statistic (0.01, p -value = 0.95). We instrument the change in the user
30 cost of R&D with the exogenous parameters of the fiscal incentive scheme, i.e. the length of
31 the first bracket and the second bracket rate, as well as the contemporaneous real R&D
32 deflator in first differences. We use a number of tests to check the validity of our instruments.
33 The rank test of under-identification rejects the null hypothesis that the matrix of reduced
34 from coefficients has less than full rank and hence points to the relevance of the instruments
35 and the identification of the model with those instruments ($\chi^2(2) = 188.27$). The Shea partial
36 R^2 is reasonable 0.21 (F-test based on this measure is 52.5, $p<0.01$). We also checked the
37 Cragg-Donald statistic (the minimum eigenvalue of the first stage F-statistic matrix) to test
38 whether the instruments are weak in terms of relative bias (the maximum relative squared bias
39 of the IV estimator relative to the OLS estimator) and in terms of bias in the Wald test size
40 (whether the actual size of the test is at least some value b above the nominal level of the test).
41 The Cragg-Donald statistic is 52.53 and at 5% level (critical value 16.85) we reject the null
42 hypothesis that the instruments bias the IV estimate relative to the OLS estimate by more than
43 5% and we do not reject the null hypothesis that the bias in the size of the Wald test exceeds
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3 10% (critical value 24.58). The Sargan test statistic is small (0.21, p-value = 0.85) and does
4 not reject the validity of the instruments. The estimated short-run user cost elasticity is -0.50
5 and the long-run elasticity -0.54, both statistically significant.
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9 Column (3) in Table 4 presents the results from equation (9). There is no particular
10 reason to include an individual effect as the equation is already in first-differences, and the
11 depreciation of R&D as well as the adjustment speed towards the desired R&D stock are
12 supposed to be constant across firms. Indeed, when we introduce the individual effects, the
13 individual effects turn out to be insignificant (F-test of the null hypothesis that all individual
14 effects are zero is 0.13, p-value = 0.98).⁶
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19 The lagged dependent variable, the change in the real user cost of R&D, and the
20 change in output are likely to be correlated with the error term. The Hausman test rejects the
21 null hypothesis that the growth rate in the real user cost of R&D, is exogenous ($\chi^2(1)$ is
22 7.95). The lagged dependent variable in (9) is also correlated with the error term because of
23 its MA(1) nature. Therefore, we instrument the change in the user cost and $R_{i,t-1}/K_{i,t-2}$ by the
24 length of the first bracket and the second bracket rate, the contemporaneous real R&D deflator
25 (in first differences), and $R_{i,t-2}/K_{i,t-3}$. The instruments are significant and valid in this
26 equation, using Sargan test (0.61, p-value = 0.89), the rank test of under-identification (52.8,
27 p-value = 0.00), and Cragg-Donald statistic (10.7), although the Shea partial R^2 for this
28 equation is somewhat smaller, 0.11. The estimated short-run user cost elasticity is -0.42 and
29 the long-run elasticity -0.79, both statistically significant.
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40 Our estimated partial adjustment coefficient of 0.5 is also quite reasonable, indicating
41 that firms accomplish half of their desired capital stock growth in every period. The output
42 elasticity is relatively low and only significant at a 10% level of confidence. The elasticity
43 with respect to the industry price is significant only at 10%. Parameter δ is estimated at 0.1
44 and is statistically significant. The output price markup and returns to scale coefficients (ζ
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54 ⁶ In the model selection process we experimented with several control variables. We included controls
55 for business cycle influences on R&D investment by using industry-specific business cycle indicators:
56 for investment potential (i.e. solvability and return on total assets) and indicators for perceived
57 competition, turbulence and economic development. These variables were constructed and provided to us
58 by EIM. None of these control variables had a significant coefficient. We also tried to control for a
59 possible size effect in the R&D investment rate by including the log of the number of employees as an
60 additional regressor. This size effect would capture, not scale effects but, differences in the speed of
adjustment of the R&D stock. This coefficient was 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 in order not to lose too many observations.

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3 and ν , resp.) are not reported because they are derived from industry and firm output
4 elasticities which are not statistically significant.⁷
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7 Both short-term and long-term price elasticities are statistically different from zero at
8 the 1% level of significance in all three specifications. We also note that the three models,
9 which differ essentially in the assumed dynamics of R&D stock accumulation, produce
10 consistent results. A 10 percent decrease in the user cost of R&D is predicted by the three
11 models to increase the R&D stock by respectively 2, 5 and 4 percent in the short run and 5.6,
12 5.4 and 7.9 percent in the long run. The estimated R&D price elasticities reported in the
13 literature vary widely depending on the data, the estimation method and perhaps the
14 underlying tax incentive system (see Hall and van Reenen, 2000, Wilson, 2007). Our
15 estimated R&D price elasticities are in the ballpark of those reported elsewhere. If ever there
16 was a systematic deviation, which would require a proper meta-analysis to control for other
17 differences in the conducted studies, it would be a lower long-run elasticity and a lower
18 spread between short-run and long-run elasticities.
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28 We ran a number of alternative specifications to test the sensitivity of our results. We
29 estimated a finite-distributed lag model similar to one employed for example by Chirinko,
30 Fazzari, and Meyer (1999). We experimented with several specifications with up to four lags
31 of u_i^R . In our preferred specification based on the Akaike information criterion with three lags
32 all short-run elasticities ($-\sigma_0, -\sigma_1, -\sigma_2$) are statistically significant. The long-run price
33 elasticity was estimated to be -0.89 and was significant. We estimated specification (11) for
34 large (200 or more employees) and small firms (less than 200 employees). As expected, the
35 estimated R&D user cost elasticity is larger for small firms (-0.57 versus -0.15 in the short run
36 and -1.1 versus -0.25 in the long run), suggesting that small firms are much more sensitive to
37 fiscal incentives. Large firms consider tax incentives more as a bonus and do not let their
38 R&D investments be greatly affected by variations in the level of tax incentives. Small firms
39 are more likely to be credit constrained and therefore more sensitive to tax incentives. As
40 expected, the adjustment speed towards the optimal R&D stock is somewhat higher for large
41 firms (0.58 versus 0.52), although the difference is statistically not significantly different from
42 zero.
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57 ⁷ Some of the reported tests can be sensitive to the presence of heteroskedasticity, in which case a more efficient
58 GMM estimator can be used. To check this, we perform several heteroskedasticity tests on residuals in all our
59 models. We use Pagan/Hall general test of heteroskedasticity for instrumental variables (IV) estimation as well
60 as the standard heteroskedasticity test of White/Koenker. These tests do not reject the assumption of
homoskedasticity of the residuals in our models.

V. Effectiveness of tax credits to R&D

On the basis of the estimated elasticity of R&D with respect to its user cost we can analyze the effectiveness of the tax credits, i.e. find out whether the additional R&D stimulated by the tax incentive policy is greater than the tax expenditures related to this program. We shall be interested in evaluating the effectiveness of the whole fiscal incentives program and not of particular aspects of it.⁸

In the absence of a proper cost-benefit calculation, that would include all direct and indirect 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). The BFTB calculates how much private R&D gets generated per Euro of R&D tax receipts foregone. It is greater than 1, R&D tax incentives are considered to be efficient in stimulating additional R&D; a value smaller than 1 means that part of the money received from tax incentives substitutes for private financing.⁹ What is important, but generally not done in this kind of evaluation, is to compare not just the present but also all future R&D and tax receipts foregone, because if firms adjust their desired R&D stock only gradually, it takes time for the additional R&D expenditures, and the associated costs to the government that go with it, to realize.

To calculate the BFTB related to the whole fiscal incentives program we evaluate the R&D (in Euros) that would be lost following the suppression of the WBSO program and the ensuing increase in the user cost of R&D to the money saved by the government for no longer having to support the program, from the time 0 that corresponds to the removal of the WBSO to the time where firms reach their new steady state in R&D stocks.

⁸ For instance, from the policy perspective, it would also be interesting to examine the effect of R&D tax credits, or changes in it, on the probability to become an R&D performer (e.g., Dagenais et al., 2004). Unfortunately, we are unable to examine this issue because our sample is limited to ‘hard-core’ continuous R&D performers, first because the Dutch R&D surveys concern only hard-core R&D performers, and secondly because we eliminate firms with less than three contiguous years of observations in order to construct R&D stocks. We have no pre-sample information and only a handful of startup firms. Finally, it would be preferable to control also for the use of direct R&D subsidies (as done in Hægeland and Møen, 2007 and Corchuelo and Martínez-Ros, 2009). We did not have this information. This might overestimate our price elasticity since part of what we attribute to tax incentives may actually be due to direct R&D support.

⁹ It goes without saying that the threshold value of 1 is no longer relevant if we include external and side effects in the benefits of the tax program and administrative and implementation costs for the firms as well as for the government in the additional costs due to the tax program.

To find out how much R&D decreases from period 1 onwards because of the removal of the fiscal incentives scheme occurring in period 0 ($\Delta u_{i,0}^R$), we have to compute the differences in R&D flows from period 1 onwards between the two scenarios, where $\tilde{R}_{i,t}$ (resp. $R_{i,t}$) denotes the flows after (resp. before) the removal of the WBOS. The flows of each additional year are discounted by $(1+r)$ vis-à-vis the previous year. This in our particular case is equal to¹⁰

$$\sum_i \sum_{t=1}^{\infty} (\tilde{R}_{i,t} - R_{i,t}) / (1+r)^{t-1} = \sum_i \sum_{t=1}^{\infty} \left[\delta \left(\frac{\partial K_{i,1}}{\partial u_{i,0}^R} + \dots + \frac{\partial K_{i,t-1}}{\partial u_{i,0}^R} \right) + \frac{\partial K_{i,t}}{\partial u_{i,0}^R} \right] \Delta u_{i,0}^R / (1+r)^{t-1} \quad (12)$$

In expression (12) we have¹¹

$$\frac{\partial K_{i,t}}{\partial u_{i,0}^R} = -\sigma\lambda(1-\lambda)^{t-1} \frac{\tilde{K}_{i,t}}{u_{i,t}^R}, \quad (13)$$

where $-\sigma\lambda$ is the estimated user cost elasticity of R&D stock in the first period, λ is the estimated partial adjustment coefficient, δ is depreciation parameter for the R&D stock, taken to be 15%, r is the risk-free interest rate, on average 3%, and where the user cost elasticity, common to all firms of a given size class and constant over time, is converted to a marginal effect for period t using the optimal R&D stock and the user cost of R&D of period t .

The cost saving for the government for no longer supporting the R&D tax credit program is denoted by W_t . The difference in government costs between the old and the new scenario is given by

$$\begin{aligned} \sum_{t=1}^{\infty} (\tilde{W}_t - W_t) / (1+r)^{t-1} &= \frac{1}{(1+r)^{t-1}} \sum_i \sum_{t=1}^{\infty} (1-\tau) w_i^L [G_{i,t}(\tilde{R}_{i,t})\tilde{R}_{i,t} - G_{i,t}(R_{i,t})R_{i,t}] \\ &+ \frac{1}{(1+r)^{t-1}} \sum_i \sum_{t=1}^{\infty} \tau\kappa(\tilde{R}_{i,t} - R_{i,t}). \end{aligned} \quad (14)$$

¹⁰ Because $\tilde{K}_{i,t-1} = K_{i,0} + (\partial K_{i,1} / \partial u_{i,0}^R + \partial K_{i,2} / \partial u_{i,0}^R + \dots + \partial K_{i,t-1} / \partial u_{i,0}^R) \Delta u_{i,0}^R$ we can write

$$\begin{aligned} \tilde{R}_{i,t} - R_{i,t} &= \delta(\tilde{K}_{i,t-1} - K_{i,0}) + (\partial K_{i,t} / \partial u_{i,0}^R) \Delta u_{i,0}^R = \delta(\partial K_{i,1} / \partial u_{i,0}^R + \partial K_{i,2} / \partial u_{i,0}^R + \dots + \partial K_{i,t-1} / \partial u_{i,0}^R) \Delta u_{i,0}^R + (\partial K_{i,t} / \partial u_{i,0}^R) \Delta u_{i,0}^R \\ &= [\delta(\partial K_{i,1} / \partial u_{i,0}^R + \partial K_{i,2} / \partial u_{i,0}^R + \dots + \partial K_{i,t-1} / \partial u_{i,0}^R) + \partial K_{i,t} / \partial u_{i,0}^R] \Delta u_{i,0}^R. \end{aligned}$$

¹¹ Given the robustness of the results across specifications, for analytical simplicity we compute the BFTB using the partial adjustment model (6).

where τ is the corporate income tax rate, $G(\cdot)$ is the fraction of the private R&D that is supported by the WBSO tax incentive program and κ is the fraction that can be immediately expensed. We can compute (14) for each period iteratively using the expression $\tilde{R}_{i,t} = \delta \tilde{K}_{i,t-1} + (\tilde{K}_{i,t} - \tilde{K}_{i,t-1})$, assuming that the factor composition of the R&D costs does not vary with the tax credit rate.¹²

The BFTB related to the removal of the entire program is given by the ratio of equations (12) and (14):

$$BFTB = \frac{\sum_i \sum_{t=1}^{\infty} (\tilde{R}_{i,t} - R_{i,t}) / (1+r)^{t-1}}{\sum_{t=1}^{\infty} (\tilde{W}_t - W_t) / (1+r)^{t-1}}. \quad (15)$$

The convergence to a new steady state is basically achieved after 15 years, i.e. $(\tilde{K}_{i,0+15} - \tilde{K}_{i,0+14})$ is negligible¹³. The BFTB computed for all firms in the sample is equal to 1.05 (standard error 0.23) one year after the removal of WBSO after which it monotonically declines to about 0.54 (standard error 0.73) 15 years after. The BFTB estimate is statistically significant in the short run (the first four periods) at the conventional levels, but its confidence interval becomes wider with t . The long-run BFTB is not statistically significant at the conventional levels. A more detailed derivation of (15) and of the computation of the standard error of the BFTB is explained in Lokshin and Mohnen (2010). According to our estimates, the decrease in R&D due to removal of the tax incentives is more than compensated by the decrease in the government tax expenditures. In other words, the introduction of the WBSO would lead eventually to less additional R&D than the WBSO budget devoted to it.¹⁴

The effectiveness of the fiscal scheme differs, however, by size class. We distinguish two size classes: the small firms with less than 200 employees and the large firms with at least 200 employees. We re-compute BFTB for the two size classes by using the estimated elasticities for each size class. One year after the removal of the program the BFTB is equal to

¹² In (14) $R_{i,t} = R_{i,0}$, i.e. the steady state level of R&D expenditures in the scenario with WBSO in place.

¹³ Because of the unbalanced nature of our sample, the reference year 0 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 (12) and (14) are taken for that particular year for each firm.

¹⁴ This conclusion does not change much when we assume a zero discount rate.

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3 3.24 (t-statistic 3.07) for small firms and 0.78 (t-statistic 4.04) for large firms. If we limit the
4 analysis to the immediate business R&D outlays and associated costs to the government, the
5 program seems to be effective in stimulating new R&D for small firms but not for large firms.
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7 If we consider the whole sequence of R&D outlays and associated costs to the government,
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9 i.e. 15 years after the removal of the program, we conclude that the BFTB drops to 1.21 (t-
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The long-term ineffectiveness of a fiscal incentive scheme like the Dutch WBSO reflects the dead-weight loss related to a level-based system of R&D tax incentives¹⁵. With a level-based R&D fiscal incentive scheme firms can apply for tax deductions regardless of their past R&D effort. The tax credit applies to the total R&D labor bill, i.e. the current incremental R&D and the level of R&D existing before the introduction of the scheme. Supporting pre-existing R&D, which was done anyway, is a dead-weight loss from the social planner's perspective. In contrast, with increment-based R&D tax incentives scheme only the additional R&D would be supported. Conversely, removing the existing scheme, as we have experimented with, would decrease R&D to an extent determined by the user-cost elasticities, but not remove it completely. For government, this measure would decrease not just the expensing related to the decrease in R&D but also the WBSO support of all present R&D. Removing the WBSO would result in regaining the dead-weight loss.

To compute the magnitude of the deadweight loss, we evaluate the WBSO support for the amount of R&D that would be done even in the absence of the program, i.e. in our experiment at the new steady state after complete removal of the WBSO, and divide this expression by the difference in revenue loss for the government with and without the fiscal incentives scheme. The dead-weight loss amounts to 85% of the total revenue loss saving due to the removal of the WBSO.

Finally, we have considered whether our conclusions would change if we allowed in our experiment for the social rates of returns to R&D, including R&D spillovers. Substantive R&D spillovers have been reported in the literature and in principle, would act as a positive counterbalance to the inefficiency of the R&D support scheme. The results of our Monte Carlo experiments (see Mohnen and Lokshin, 2010 for details) suggest that spillovers have to

¹⁵ Although we acknowledge that small firms are underrepresented in our sample it does not seem to affect our conclusions about the dead-weight loss of the level based program. To check how sensitive our outcomes are for the sample composition, we conducted Monte Carlo simulations in which we mimicked population of R&D performers in The Netherlands. The results of these experiments do not change the substantive conclusions and are described in more detail in Mohnen and Lokshin (2010).

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3 be sizeable to compensate for the deadweight loss. Even with a social rate of return as large as
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5 50% there can be a net welfare loss when introducing level-based tax incentives if
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7 administration and compliance costs and the costs associated with tax distortion are
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9 considered.

10 11 **VI. Conclusions**

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16 In this paper we have assessed the effectiveness of the R&D fiscal incentive program in the
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18 Netherlands, which consists in reducing the employer's social security contributions in
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20 proportion to the R&D wage bill. We have estimated dynamic factor-demand models based
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22 on a CES production function to measure the responsiveness of a firm's R&D capital
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24 accumulation to changes in its user cost due to changes in R&D tax incentives. We have
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26 estimated our econometric models on a firm-level sample covering 1996-2004. The richness
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28 of the dataset allowed us to construct firm-specific R&D user costs as a function of R&D tax
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30 incentives. The results suggest that R&D is responsive to its user cost. We obtain a
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32 statistically significant short-run elasticity of the order of 0.2 to 0.5 and a significant long-run
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34 elasticity of the order of 0.54 to 0.79. According to our preferred specification the adjustment
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36 speed to the new optimal R&D knowledge level is quite high, 90% of the adjustment being
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38 completed within 2-3 periods.

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40 To evaluate whether a level-based R&D incentives program is successful we have
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42 performed policy experiments in which we simulated the reduction in R&D following the
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44 suppression of the fiscal program. By calculating the amount of the decrease in R&D in the
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46 absence of the tax incentives and comparing it to the decrease in present and future tax
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48 expenditures related to the fiscal incentives we have computed the so-called "bang for the
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50 buck" (BFTB), given by the ratio of these two amounts. The results suggest that for small
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52 firms the hypothesis of crowding out can be rejected and that the fiscal incentives program is
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54 successful in stimulating small firms' investment in R&D especially in the short run. For
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56 large firms the Dutch R&D support program does not look to be effective. From the
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58 beginning the deadweight loss overshadows the increase in R&D generated from the program.

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60 The BFTB decline is due to the level-based nature of the scheme, meaning that firms
can apply for the wage tax deductions for the current year regardless of their past R&D
efforts. As a result, the cost to the government of a level-based scheme in our experiment
grows faster than the incremental (additional) firm R&D that such a program stimulates. This
deadweight loss is typical for level-based R&D tax incentives and would not occur in

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3 incremental R&D tax incentives. If recently various governments seem to steer away from
4 incremental R&D tax incentives, there must be other reasons for it that we have not
5 investigated (e.g. higher administration costs). The deadweight loss is immediately visible for
6 large firms (the bang-for-the-buck being smaller than one from the first period on) and is also
7 significant for small firms. Bringing forward the extent of this invisible deadweight loss
8 associated with a level-based R&D support program, such as the WBSO scheme and similar
9 level-based fiscal R&D support programs elsewhere, is the main message of this paper.

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11 An interesting avenue for future research would be to estimate whether the R&D
12 stimulated by tax incentives and the R&D done in the absence of tax incentives have different
13 returns. After all, there are good reasons to believe that the additional R&D would have been
14 done anyway if it yielded a higher return than the R&D done in the absence of tax incentives.
15 In the experiments we also did not take into account a possible price effect of R&D tax
16 incentives. Some of the government support may get dissipated in higher R&D wages instead
17 of real R&D spending. If that is the case, the benefit from tax incentives might be
18 overestimated. And, finally, as already mentioned, it would be interesting to estimate the
19 effect of tax incentives on the probability to engage in R&D. Bringing firms to become R&D
20 performers is perhaps the major goal of R&D tax incentives, and since these firms did no
21 R&D beforehand, for these firms there is no deadweight loss.
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Table 1 Overview of 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	253	68067	40	12.05	4.5
1997	274	68067	40	12.5	6.8
1998	372	68067	40	17.5	6.8
1999	353	68067	40	13	6.8
2000	365	68067	40	13	6.8
2001	435	90756	40 or 60 (s)	13	7.9
2002	464	90756	40 or 70 (s)	13	7.9
2003	425	90756	40 or 60 (s)	13	7.9
2004	466	110000	40 or 60 (s)	14	7.9

Source: de Jong and Verhoeven (2007); (s) stands for 'starters'

Table 2 Variable constructions and descriptive statistics

Variable	Construction	Mean	Standard Dev.
R/K	R&D expenditure to R&D stock constructed at the beginning of the period	0.19	0.29
U^R	User cost of R&D (see construction in Appendix A)	0.26	0.06
v	Firm output in logarithm*	16.27	1.36
q_I	Mean 2-digit industry output in logarithm *	18.05	1.02
Δu^R	Growth rate in user cost	0.04	0.23
Δv	Growth rate in firm output	0.03	0.35
Δq_I	Growth rate in industry output	0.11	0.35
K	R&D capital stock*	20.2	74.5

Note: The sample means and standard deviations are taken for the years 1996-2004. * in million 1994 Euro

Table 3 Annual average user cost of R&D and its components

Year	User cost of R&D without R&D tax incentives	B-index	User cost of R&D with R&D tax incentives
	(1)	(2)	(3)
1997	0.308	0.833	0.258
1998	0.298	0.815	0.243
1999	0.306	0.806	0.246
2000	0.311	0.797	0.248
2001	0.309	0.791	0.245
2002	0.334	0.803	0.268
2003	0.364	0.815	0.298
2004	0.388	0.808	0.314

Notes: The B-index (column 2) measures the net cost per Euro of R&D after deduction of all R&D tax incentives divided by after tax return on one Euro of revenue. Column (3) is a product of column (1) and column (2).

Table 4. Estimation of R&D equation (14) by instrumental variables

Dependent variable	$k_{i,t}$	$\frac{R_{it}}{K_{i,t-1}}$	$\frac{R_{it}}{K_{i,t-1}}$
	Simple dynamic model (eq. 8)	ECM (1,1) model (eq. 15)	Partial adjustment model (eq. 13)
$\frac{R_{it-1}}{K_{i,t-2}}$ R&D flow/stock	--	--	0.47*** (0.13)
$k_{i,t-1}$ ln(R&D stock)	0.62*** (0.04)	-0.89*** (0.06)	--
$d(u_{i,t}^R - p_{i,t}^I)$ d(ln user cost)	--	-0.50*** (0.18)	-0.42*** (0.14)
$u_{i,t}^R - p_{i,t}^I$ ln(user cost)	-0.21*** (0.05)	--	--
$u_{i,t-1}^R - p_{i,t-1}^I$ ln(lagged user cost)	--	-0.48*** (0.18)	--
dv_{it} dln(output)	--	0.05 (0.04)	0.06* (0.03)
$v_{i,t}$ ln(output)	0.14** (0.06)	--	--
$v_{i,t-1}$ ln(lagged output)	--	0.08* (0.04)	--
dq_{iit} dln(industry output)	--	0.09* (0.04)	0.05 (0.03)
$q_{i,t-1}^I$ ln(lagged industry output)	0.01 (0.01)	0.13* (0.05)	--
δ	--	--	0.10*** (0.03)
Long-run user cost elasticity	-0.56*** (0.15)	-0.54*** (0.20)	-0.79*** (0.35)
Time dummies	Included	Included	Included
Individual effects	Fixed	Fixed	--
Sargan test (p-value)	5.18 (0.16)	0.21 (0.97)	0.61 (0.89)
Number of observations	1185	1185	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.

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