R&D TAX POLICY and FIRM DYNAMICS

Orkhan Hasanaliyev *
The University of Iowa

Abstract

Empirical studies have documented the cost effectiveness of the R&D tax credit policy implemented in the US since 1981. However those studies fail to take into account the effect of R&D decisions on firms' evolution over time. We construct a dynamic general equilibrium model of R&D with externalities where, a firm's dynamics are affected by its own R&D decisions and by the R&D investment of other firms. The model is calibrated to pre-1981 US manufacturing data. We confirm the cost effectiveness result of empirical studies. However, we find that at its current 20% rate, the tax policy is welfare reducing, and that the optimal tax credit rate should be 3.8 %.

*I would like to thank my advisor Matthew Mitchell for his continuous encouragement. I also thank Ayca Kaya, Fernando Leiva, B. Ravikumar, Galina Vereshchagina and seminar participants at the University of Iowa for their helpful comments and suggestions

1 Introduction

Technological innovations are one of the main sources behind economic development and welfare. Many countries have adopted policies to encourage firms to innovate. The main reason behind such policies is the spillover effects exhibited by R&D activities. Because of the externality effect, if R&D activity is left solely to the market, there will be an underinvestment in it. Therefore, fixing this externality requires some kind of government intervention. In most industrialized countries a variety of incentives have been introduced to overcome this kind of externality problem. In this paper, we evaluate the impact of one of those policies. In 1981, under the Economic Recovery Tax Act, the so called Research and Experimentation Tax Credit was introduced. Initially, the tax credit rate was 25 percent on *incremental* increases in R&D investment, with the tax base being the maximum of the previous three years' average or 50% of the current year.[1] Later, the tax rate was changed to 20 percent with no change in tax base definition.

The goal of this paper is to evaluate the impact of this policy. To this end, we construct a dynamic model of R&D with externalities, calibrate it to pre-1981 US data and evaluate a policy that mimics the US policy. Consistent with earlier empirical studies, we find that the 20 percent tax credit rate implemented in the U.S. on incremental R&D investment has a positive impact on the total R&D investment. The model replicates the finding that tax price elasticity of R&D spending is greater than 1: each foregone dollar in tax revenue on average stimulates 1.513 additional dollars of R&D investment. However, the model shows that even in such a case, the policy might reduce both welfare and total productivity.

The main channel that leads to these results is the impact of the tax policy on the distribution of R&D spending across firms. First of all, the tax policy shifts the R&D distribution towards smaller firms. It encourages more firms to perform R&D activity. However, these new R&D firms are relatively less efficient in performing R&D activities. Second, under the policy regime, firms that make an R&D investment adjust their R&D levels frequently. While firms of the same

[1]Similar to the US, many countries have tax incentives for R&D activities, including the incremental tax credits. However tax credit rates and tax base definition varies across countries. For a cross country summary and comparisons see Hall and Van Reenen (2000), and Bloom et. al (2002)

size undertake the same amount of R&D in a no tax credit policy regime, under the tax policy regime, their R&D investment levels vary. Firms that experience an expansion are encouraged by the policy to intensify their R&D investment, while those that undergo a contraction are discouraged from investing more. Firms that experience a good shock increase their R&D investment levels in order to immediately benefit from the tax credits. However, firms that experience bad shocks decrease their R&D levels hoping to benefit from it in the future, since it lowers their tax base. These two effects lead to inefficient allocation of resources across firms. These negative effects of the policy are counterweighed by the positive contribution of R&D activities toward productivity increase via spillover effect. If the tax credit policy is too generous, costs associated with inefficient allocation of resources overcome productivity benefits of the policy, leading to an overall decrease in total productivity, and consequently to welfare losses. Even though the tax subsidy is necessary to overcome the externality problem, at the current rate it is too generous and it overshoots the optimal rate, which we find to be 3.8 percent.

The current paper modifies the Hopenhayn and Rogerson (1993) environment by introducing R&D decisions through which firms can affect their productivity process. Since we see firms' R&D decisions as having an influence on firm's evolution over time, the industry dynamics model of Hopenhayn and Rogerson with heterogenous firms - where firms can expand, contract, enter and exit over time - provides us with an appropriate set up to start with. However, unlike Hopenhayn and Rogerson, the stochastic process in the model is endogenous and is driven by the R&D decisions. Firms also experience an externality from others' R&D investment. Our framework makes it possible to analyze how firms' behavior (dynamics) interact with their own and other firms' R&D decisions. The model is constructed in such a way that, in the absence of externality, any tax distortion is harmful in welfare terms. However, with the externality, firms have the incentive to free-ride on others' R&D effort, so that the equilibrium without the tax credit is no longer the optimal one. Therefore, there is a role for government intervention. The economy without tax credit is calibrated to pre-tax US manufacturing data, which is the period before 1981. A unique feature of our calibration is the way that we have pinned down the externality effect. We calibrate a parameter that governs the externality effect of R&D investment to match the fraction of firms that perform R&D, while the model's other parameters are chosen such that firm dynamics moments in the model are consistent with the corresponding data moments. The model is rich enough to analyze the impact of the tax policy not only on an individual firm's behavior, but also on macroeconomic variables, a feature absent in the previous literature.

This paper is not the first one addressing the effectiveness of tax credit policy. Many researchers have attempted to assess the impact of this policy. Mixed results were reached with the most recent contributions emphasizing that the policy was successful overall [2]. In assessing the effect of the policy the literature focuses on estimating the average tax price elasticity of R&D spending. It was concluded that the policy was effective when the additional increase in total R&D investment induced by the policy exceeded the total amount in foregone tax revenue. Our framework suggests why it would be wrong to draw a conclusion about the effectiveness of the policy by focusing only on the average tax price elasticity.

First, firms perform an R&D activity to affect their productivity and growth. Therefore, to understand how firms will respond to the introduction of the tax credit policy it is important to know how R&D decisions are made in the first place and how these decisions are linked to firm's productivity. Hence, it would be stopping short to analyze only R&D investment response to the tax incentive without taking into consideration the effect of R&D investment on productivity. This paper adds a new channel that links a firm's R&D decisions to its productivity.

Second, in assessing the economy wide impact of the policy mere summation of additional R&D investment as a result of the tax policy means taking a position that all firms have the same marginal contribution toward the total productivity. However, firms are heterogenous in their productivity levels and each firm's

[2]Early works on the subject by Eisner, Albert and Sullivan (1984) and Altshuler (1988) find that tax credit has a negligible effect on the R&D spending, if not a negative one. Mansfield (1986) based on surveys of a sample of firms' top executives find an R&D price elasticity to be between 0.3 and 0.4. However, none of those works did apply formal econometric techniques to single out the tax credit effect on R&D investment. Later works of Berger (1993) and Hall (1993) that formally estimate the tax price elasticities conclude that it is 1.74 and 2, respectively. For a literature review on this field see Hall and Van Reenen (2000)

marginal contribution to the total productivity can be affected differently by the introduction of the tax policy. Therefore, the focus should be not only on the impact of the policy on net change in total R&D investment, but on change in total productivity.

Third, since the main goal of the policy was to fix the externality effect arising from R&D activities, it is not clear whether the current tax credit rate is the optimal one. Unlike the previous literature, which ignored the externality effect, our framework allows us to analyze its impact and calculate the optimal tax credit rate.

Lastly, previous studies did not analyze the effect of the tax credit policy in a general equilibrium framework. Even in the absence of externality, the tax policy may still be cost effective, but it would be incorrect to conclude the policy's success by relying solely on its cost effectiveness. It is our general equilibrium framework that allows us to fully explore the aggregate effects of the policy.

The paper is organized as follows. The next section describes the model economy. Section 3 calibrates the model to US manufacturing data. Section 4 analyzes the effect of tax credit policy. Section 5 concludes the paper. All theoretical results are provided in the Appendix.

2 Model

Our model economy closely follows the Hopenhayn and Rogerson (1993) environment. However we modify their environment by allowing firms to undertake R&D activities to affect their evolution over time.

The economy is populated by a large number of firms each of which has an access to a production function, $f(m, n)$, which is homogenous of degree one in the productivity level, m, and the labor input, n [3]. We assume that production does not require any fixed cost and both labor and output markets are competitive.

[3]This assumption is required to get the result that with no externality R&D intensity is constant across firms. Because m is unitless, all quantitative results of the paper can be delivered under other production specifications.

Instantaneous profit of a firm with productivity level m that hires n workers at competitive wage w is

$$\pi(m, n; w) = f(m, n) - wn \tag{1}$$

Note that the output price is normalized to one and hence omitted from the above expression. With constant returns to scale production technology each operating firm's optimal instantaneous profit $\pi^*(m)$ and labor demand $n^*(m)$ are linear in m given wage rate, w. In addition to production technology, each firm is also able to undertake an R&D investment to affect its future productivity levels. Controlled stochastic process that generates firm's next period productivity level is $m' = zm^{1-\gamma}(r + aR)^{\gamma}\epsilon$, where $z > 0$, $0 < \gamma < 1$, $a > 0$ and support of m is $[\underline{m}, \infty)$.[4] This process requires some explanation. Firm's future productivity level, m', besides the disturbance ϵ, depends on firm's current productivity level, m, on firm's R&D investment level, r, and on the economy's average R&D investment level, R. Dependence of firm's future productivity level on the aggregate R&D investment reflects the spillover effect of R&D activities. The assumption that $a > 0$ indicates that firm's own R&D and aggregate R&D are substitutes. This assumption is consistent with both previous theoretical models (Reinganum (1981), Spence (1984)) and empirical findings (Bernstein and Nadiri (1989), Cohen and Levinthal (1989)). We assume that the disturbance, ϵ, is from the Laplace distribution with parameters (μ, σ) [5]. Note also although firms can perform R&D activities, the model is absent from R&D competition among firms which is the focus of large IO literature. Instead in the model, firms produce the homogenous good and the output market is competitive. We acknowledge that strategic aspect of R&D investment is important one and the pressure from competitors is detrimental for undertaking an R&D activity. However in this paper, our focus is on macroeconomic implications of R&D decisions and for a moment we put aside its strategic aspect. So each firm is treated as infinitesimally small comparing

[4] The controlled Markov process for productivity shocks can be expressed in more general form. Denoting this process by $F(m, r, R, m')$, the following assumptions are sufficient for our results: 1) F is decreasing in its first three arguments. 2) $F_{12} > 0$ and $F_{13} > 0$. It can be easily checked that our specification for the stochastic process satisfies these conditions.

[5] Laplace distribution is a double exponential distribution. This assumption is made to simplify analysis of the model and make models predictions in line with stylized facts. Another reason for using this assumption is its better fit of firm growth rate distribution comparing to normal distribution. For the same parameter values, normal distribution is heavy tailed comparing to Laplace distribution.

to the whole economy and they do not face R&D competition from other firms. Firm's only benefit of performing an R&D activity is its effect on firm's own productivity and profitability and not of being one step ahead of others and/or dominating the market.

Government encourages R&D activities by implementing a tax credit policy. Tax credit applied toward incremental increases in R&D investment can be expressed in the following functional form, $g(r_t, r_{t-1}) = \tau \max(0{,}r_t - r_{t-1})$. To be eligible for a tax credit, firm's current period R&D investment level, r_t, must be above its previous year R&D level, r_{t-1}, in which case the firm is credited τ fraction of the increase. We assume that government finances R&D subsidies by imposing a lump-sum tax on consumers income.

Since firm's productivity level, m, maps one-to-one to its size, firm's growth rate now depends not only on its size but also is influenced by its own R&D activity and spillovers from other firms R&D investment. If R&D investment is positively related to firm size, then the negative effect of size on firm's growth can be compensated to some degree by R&D investment.[6] Moreover, R&D spillovers positively contributes to firm growth, holding other factors constant. For our stochastic process specification, both firm's expected growth rate and its variance are increasing in R&D activity [7]. Therefore, if a firm increases its R&D investment, its expected growth rate increases but so is its variance [8]. Hence, firm's R&D investment decision can be seen as a classical mean-variance problem.

Conditional on survival, at the beginning of each period, a firm decides its production level by choosing employment level and what amount of R&D to undertake. Then it observes the value of its next period productivity level. Depending on the magnitude of the shock the firm either exits the industry or stays active in the next period. If firm exits the industry, it collapses as a physical body, and receives zero profits in all future periods. An exogenous exit is as-

[6]In Appendix, we test whether R&D firms growth rate are significantly greater than non-R&D firms.

[7]See Appendix for this claim

[8]This also means that among firms of the same size, firms with high R&D level draw their next period productivity levels from a distribution that first order stochastically dominates distributions with low R&D levels. But the variance of their next period productivity distribution is larger as well.

sumed[9]. Firms that receive their productivity levels below $\underline{m}$ exit the industry at the beginning of next period. The above specification of the controlled Markov process for productivity level insures that a firm life is almost surely finite.

As some firms exit the industry, others enter into it. There is a large number of potential entrants that can replace firms that exit. Entering the industry requires a one-time cost of c_e. Upon paying this cost a firm enters the industry and gets the access to production technologies as incumbents do. We assume that new entrants receive their initial productivity levels from exponential distribution with parameter υ and origin $\underline{m}$. These shocks are independently and identically distributed across entrants and independent of the number of entrants. We assume that entrants initial R&D level is zero and entrants are not eligible for tax credit in the first period of their activity [10]. After entering the industry, new firms evolution over time follows the same process as incumbent firms do.

2.1 Labor Supply

There is a continuum of identical agents of measure one with preferences

$$\sum_{t=1}^{\infty} \beta^t [u(c_t) - v(n_t)]$$

where $c_t > 0$ is consumption and $n_t \in \{0, 1\}$ is labor supply in period t. In order to convexify the consumption possibilities set, we follow Hansen (1985) and Rogerson (1988) by assuming that individuals choose employment lotteries and have access to markets to diversify idiosyncratic risk. A lottery determines whether or not the individual works. Since all individuals are ex ante identical, all will choose the same lottery, however ex post individuals will differ depending on the outcome of the lottery. A fraction of individuals will work and the other fraction will not. Therefore, the economy can be seen as the one of representative agent with preferences defined by

$$\sum_{t=1}^{\infty} \beta^t [u(c_t) - AN_t)]$$

[9] Unlike Hopenhayn and Rogerson (1993), we assume exogenous exit. Quantitatively, endogenizing the exit process will not make much difference, since most of the firms that exit are small firms that do not perform an R&D activity.

[10] Under the current code, tax credit is not applicable to start up firms.

where N_t is the fraction of employed individuals in period t. It is assumed that individuals hold the ownership of the production technology and all shares in firms are equally distributed across individuals.

2.2 Firms' Decision Problem

We restrict our analysis to stationary equilibrium only. In the stationary equilibrium aggregate variables stay constant over the time, however individual firms could expand, contract, entry and exit the industry. It is this dynamism in our view that should be taken seriously in analyzing the effects of any policy that distorts firms' decisions.

To save space we suppress firm's labor decision in the following Bellman equation and instead display optimal profit function, $\pi^*(m)$, associated with that decision. Also let $h(m,r,R) \equiv zm^{1-\gamma}(r+aR)^{\gamma}$. An incumbent firm that had a productivity level m and made an R&D investment r in the previous period, face the problem that can be expressed by the following Bellman equation

$$V(m,r;w,R) = \max_{r' \geq 0}\{-r' + \pi^*(m) + g(r',r) + \beta \int_{\underline{\varepsilon}}^{\infty} V(h(m,r',R)\varepsilon, r'; w, R)\frac{e}{2}^{-|\varepsilon-\mu|\sigma}\sigma dm'\}$$

Where $\underline{\varepsilon} = \frac{m}{h(m,r',R)}$. For an entrant firm the Bellman equation takes the same form except that tax credit does not apply toward their R&D investment level in the first period, i.e $g(r',0) = 0$ for any r'. Using the change of variables, $dm = hd\varepsilon$, the Bellman equation can be reformulated as.

$$\begin{gathered} V(m,r;w,R) = \max_{r' \geq 0}\{-r' + \pi^*(m) + g(r',r) + \\ +\beta \int_{\underline{m}}^{\infty} V(m',r';w,R)\frac{e}{2}^{-|\frac{m'}{h(m,r',R)}-\mu|\sigma}\frac{\sigma}{h(m,r',R)}dm'\} \end{gathered}$$

A firm should decide how much R&D activity to undertake and how many workers to hire. The choice of the first one requires a dynamic consideration, however the choice of the second one is obtained by solving a static profit maximization problem. With the knowledge of V, the value of entering into the industry can be obtained by

$$V^e(w,R) = \int_{\underline{m}}^{\infty} V(m,0;w,R)e^{-(m-\underline{m})\upsilon}\upsilon dm$$

Let's denote the optimal choice of R&D level by $r'(m,r;w,R)$ and optimal employment level by $N(m,r;w,R)$. Determination of aggregate variables from firm level ones requires the knowledge about the distribution of the state variables for all firms. Let the distribution of incumbents be summarized by measure $\lambda(m,r)$ and the mass of entrants be Λ. Then the distribution of incumbents in the beginning of the next period after the occurrence of exit will be given by some measure $\lambda'(m,r)$. Denote the transition from $\lambda(m,r)$ to $\lambda'(m,r)$ by $\lambda'(m,r) = T(\lambda,\Lambda;w;R)$.

Aggregate output, Y, can be obtained by integrating the output produced by individual firms over the active firms

$$Y(\lambda,\Lambda;w;R) = \int f(m,N(m,r;w,R);w,R)d\lambda(m,r) +$$
$$+\Lambda \int_{\underline{m}}^{\infty} f(m,N(m,0;w,R);w,R)e^{-(m-\underline{m})\upsilon}\upsilon dm$$

The first integral aggregates the output of incumbent firms and the second one does the same for the entrants. Other aggregate variables can be obtained in the similar way. Aggregate R&D and aggregate tax credits are given by

$$R(\lambda,\Lambda;w;R) = \int r'(m,r;w,R)d\lambda(m,r) + \Lambda \int_{\underline{m}}^{\infty} r'(m,0;w,R)e^{-(m-\underline{m})\upsilon}\upsilon dm$$

$$TR(\lambda,\Lambda;w;R) = \tau \int (r'(m,r;w,R) - r)X_{r'-r}d\lambda(m,r)$$
$$where \;\; X_{r'-r} = \begin{cases} 1, \; if \; r' - r > 0 \\ 0, otherwise \end{cases}$$

Note that since start up firms are not eligible for the tax credit, incumbent firms do not get any tax credit and hence are omitted from the above expression.

Aggregate labor demand and aggregate profits are given by

$$L^d(\lambda,\Lambda;w;R) = \int N(m,r;w,R)d\lambda(m,r) + \Lambda \int_{\underline{m}}^{\infty} N(m,0;w,R)e^{-(m-\underline{m})\upsilon}\upsilon dm$$

$$\Pi(\lambda, \Lambda; w; R) = Y(\lambda, \Lambda; w; R) - wL^d(\lambda, \Lambda; w; R) - R(\lambda, \Lambda; w; R) + TR(\lambda, \Lambda; w; R) - \Lambda c_e$$

It is easy to see that T operator and all aggregate variables are linearly homogenous in λ and Λ jointly.

We close this section by describing the consumer's problem. Since aggregate variables and prices are constant in the stationary state, consumer's dynamic optimization problem boils down to a static optimization problem of the following form

$$\begin{aligned} &\max_{c,N\geq 0} u(c) - AN \\ s.t. \quad & c \leq wN + \Pi - TR \end{aligned}$$

where Π is profits and TR is taxes. Let $N = L^s(w, \Pi - TR)$ be the solution to this problem.

2.3 Stationary Equilibrium

Definition 1 *A stationary equilibrium for the economy is a value function V, policy functions, r' and N, a wage w^*, a mass of entrants Λ^*, a measure of incumbents λ^* and average R&D investment R^* such that*

- *at price w^*, the policy functions solve the optimization problem of each firm*
- *the probability measure, λ^*, is time invariant, $T(\lambda^*, \Lambda^*; w^*, R^*) = \lambda^*$*
- *Labor market clears,*
  $L^d(\lambda^*, \Lambda^*; w^*, R^*) = L^s(w^*, \Pi(\lambda^*, \Lambda^*; w^*, R^*) - TR(\lambda^*, \Lambda^*; w^*, R^*))$
- *Aggregate R&D investment is consistent with firms' R&D decisions,*
  $R^* = R(\lambda^*, \Lambda^*; w^*, R^*)$
- *and new firms are willing to enter,*
  $V^e(w^*, R^*) \leq c_e$ *with equality if* $\Lambda^* > 0$

3 Calibration

In this Section, we calibrate the benchmark model to pre-1981 US manufacturing sector data. The benchmark model is absent from tax credit policy and so is the pre-1981 period. Since most of the R&D activities are performed at firm level, the unit of observation is a firm or company. The time period is equal to one year. The discount factor β is set to 0.96, which corresponds roughly to 4 percent annual interest rate. Parameter α is chosen to be 0.36 therefore labor's share of total output is 0.64. We implicitly assuming that the rest of the output is attributable to factors other than labor. Therefore, m includes all other factors including capital. The upper bound for m is chosen such that in the equilibrium the employment size at the largest firm to be 100000 workers. Similarly, the lower bound is chosen such that the smallest firm has 1 worker. Wage rate can be normalized to any value and the value of entry cost, c_e, can be chosen to satisfy free entry condition with equality. We chose the wage rate such that at the equilibrium average R&D investment matches the average of firm R&D expenditures between 1970-1981 years calculated in 1992 constant prices. The preference parameter A is chosen such that 80 percent of the population is employed, roughly the percentage of the working age population that is employed in the US. The choice of parameter a is important in determining the willingness of firms to perform R&D activity. The larger its value the bigger R&D spillover effect, ceteris paribus, and the greater the incentive to free ride off others' R&D effort. Hence, the choice of a is detrimental for the number of R&D firms. We set the parameter a to match the fraction of firms performing R&D activity. This fraction is 4.65% for the US data. The number of manufacturing firms performing R&D is obtained from NSF statistics and the number of manufacturing firms from Bureau of Census Enterprise Statistics. These numbers are averaged over 1963,1967,1972, 1977 and 1982 years. The rest of the parameters z, γ, μ, σ and υ are set to be consistent with firm dynamics statistics. Moments we chose to match are mean and variance of firm employment size, which are obtained from Enterprise Statistics. The other piece of data we use is job creation and job destruction rates. Job creation and destruction are defined like in Davis and Haltiwanger (1990). Job creation at time t equals employment gains summed over all firms that expand or start up between period $t-1$ and t, divided by the average employment level. And similarly, job destruction at time t equals employment losses summed over all firms that contract or shut down between period $t-1$ and t divided by average employment level. Since in the data job creation and job destruction rates are not equal, we chose the average of these two rates as one of the moments to be matched. Another moment that was chosen to be matched is the job creation rate due to birth. And lastly, we choose firm exit rate as provided by Dunne, Roberts and Samuelson (1989) to be reproduced by the model economy. The average annual exit rate is about 8.6%.[11]

Table 1 lists values for parameters and Table 2 shows the moments that were chosen to be matched and their corresponding values both in the data and in the model. Table 3 shows that the model economy performs a reasonable job in replicating the pre-1981 period US manufacturing firm data. Since the model parameters are chosen to match the above mentioned moments, to evaluate how good the model fits the data it is appropriate to look at model's performance in mimicking the data at the dimensions other than the targeted ones. Table 4 shows firm size distribution in data and the one generated by the model economy. The model very closely replicates this distribution. Table 5 displays the R&D distribution by firm size and Table 6 shows additional moments for R&D firms, both for the US data and the model economy. It should be notes that moments in Table 4-6 are not the ones that the model parameters were calibrated to. However, the model economy reproduces those statistics fairly well.

4 Results

This section compares how the economy is affected by the introduction of the tax credit policy. As mentioned earlier this is a tax credit that is applied toward incremental increases in R&D investment. We report the results for tax credit rate $\tau = 0.2$, the rate actually implemented in the US since 1981, and for the $\tau = 0.038$, which we find to be the optimal tax credit rate [12]. First note that if

[11] Dunne, Roberts and Samuelson (1989) report five-year exit rates between consecutive census years. The average five-year exit rate is 36.3%.

[12] By the optimality we mean the allocations that maximize the social welfare. And by optimal tax credit rate we mean the rate within the class of incremental tax policies.

there were no spillover effect from R&D activities, the equilibrium of the economy with no tax policy would be the optimal and any government intervention would be welfare reducing. However in the presence of externality, equilibrium of the benchmark model is no longer the optimal one. Therefore, there may be a welfare improving role for the tax policy, however a priori it is not clear what that optimal rate is and whether the current rate is the optimal one. Table 6 shows how the steady state equilibrium is affected under different tax credit rates. First note that as the tax rate increases average R&D investment increases. An additional R&D investment induced by the tax policy on average is larger than the forgone tax revenues. In fact for $\tau = 0.2$ average tax price elasticity of R&D investment is 1.513 which is in the range that was reported by empirical studies[13]. However, despite this cost effectiveness of the tax policy, it has negative welfare effects.

There are two effects that should be considered. One effect is due presence of tax credits and the other one is the spillover effect. Availability of the tax credits provides an incentive for non R&D firms to undertake R&D activity. However, for R&D firms its effect is two folded. For R&D firms tax credit creates an incentive to adjust their R&D investment levels frequently. Figure 3 illustrates R&D decision rule, for a firm of size 85000 in a no tax credit and $\tau = 0.2$ environments. Note that for a non R&D firms $r' = 0$ for all r. In a no tax credit regime, firms R&D investments only depends on their productivity level. Hence, current period R&D investment is independent of the previous period R&D level. This policy rule is represented by straight horizontal line. By introducing tax credits, R&D investment become more volatile. Firms with the same size now undertake different amounts of R&D activity. In fact R&D decisions are characterized by two cutoff points, $r_1(m)$ and $r_2(m)$. If previous R&D level is below $r_1(m)$ a firm adjusts its current R&D investment to some fix level say $r'_1(m)$. If previous R&D level is above $r_2(m)$ firm adjusts its current R&D investment to $r'_2(m)$. If previous R&D level is between $r_1(m)$ and $r_2(m)$ firm's current R&D investment become a decreasing linear function of its previous R&D level. Note that this piecewise linear relationship comes from the linear structure of tax credits. Firms that experience relatively good shocks, in order to get an immediate benefit from the policy increase their R&D expenditures. However, firms experiencing relatively

[13] Baily et al. (1992), Berger (1994) and Hall (1993) estimates of average tax price elasticity are 1, 1.74 and 2 respectively.

low shocks decrease their R&D expenditures hoping to benefit from it in the future, since this will lower their tax base. Table 8 quantifies this dispersion by displaying variance of R&D growth rate for both economies. Overall, tax credit policy increases the total R&D investment level. Although, because of spillover effect the increase in total R&D somewhat discourages firms from undertaking R&D investment, this effect is of secondary importance. Figure 4 and Table 8 show that the distribution of R&D firms shifts to the left, implying that despite the discouraging effect of spillover effect, non-R&D firms are encouraged by the policy to invest in R&D. Increase in the R&D investment level also shifts firm size distribution to the right, increasing the average firm size. So there are more large firms under the policy regime. Although, this increases the total output, the net output (total output- total R&D) is now lower. However, increase in total output drives wages and employment level up. The fact that net output decreases while consumption increases under the tax policy is due to a decrease in the number of entrants because higher wage rate deters firms from entering. Although consumption is higher under the policy regime, households also work more, which in overall lowers consumer's welfare. Table 7 shows the percentage consumption decrease, uniform across all dates, needed to be taken from household in the steady state of τ=0.2 policy regime to equate their welfare to the one under no policy regime. As Table 7 displays that on average it costs 15158$ to consumers to subsidies each firm, but it stimulates 22940$ of additional R&D investment per a firm. However, this cost effectiveness is not translated to welfare improvement.

Be there no externality, any government intervention would be welfare reducing. Any subsidy toward R&D investment would result in inefficient allocation of R&D activities across firms. In the presence of spillovers, subsidies may improve the economic well being of consumers. However, if tax credits are too generous the policy may be welfare reducing as well. In the model, tax policy shifts R&D distribution to the left, implying that many less productive firms are performing R&D under the policy regime. However, such an increase in the number of R&D performing firms is inefficient, since these new R&D firms are less efficient in performing R&D. It is actually this inefficiency combined with inefficiency associated with disturbing R&D firms decisions that leads to less net surplus in the economy and hence to lower welfare. If the tax credit policy is too generous, costs associated with this inefficient allocation of R&D activity in the economy overcomes its benefits. We find that in our model economy optimal tax credit rate should be 3.8 percent. It is interesting to see that the economy with optimal tax credit rate is not only more efficient in welfare terms, but it is also more cost effective than the one with $\tau = 0.2$. Average tax price elasticity in the optimal tax environment is 1.875 comparing to 1.513 in the current $\tau = 0.2$ regime.

5 Conclusion

This paper analyzes the impact of tax credit policy in a general equilibrium framework. Our environment allows us to study long run economy wide consequences of the tax credit policy. Unlike the previous literature on this topic, the model gives the opportunity to evaluate the policy's effectiveness, by going beyond the measure that were used in the literature, namely cost effectiveness measure. We show that using only this measure may lead to incorrect inferences. Similar to results of the previous literature, we find that R&D tax credit policy with current rates is cost effective, however it is not welfare improving. Moreover, we find that current tax credit rate is too generous and it should be much lower, at the rate 3.8 percent. We conclude that the effect of the policy on the redistribution of R&D activities in the economy should be taken into consideration in designing tax credit policy. The policy should not encourage firms that are less efficient in performing R&D to undertake this activity.

The model abstracts from the growth effects of R&D investment. The impact of R&D investment on firm dynamics is not translated to economic growth. However large body of growth literature emphasizes the importance of R&D activities for an economic growth. The spillover effect of R&D activities may be larger if they affect the growth rate. It is a useful exercise to explore the policy effect in a growth model context.

6 References

Altshuler, Rosanne (1988).“A Dynamic Analysis of the Reasearch and Experimantation Credit”. *National Tax Journal*, 41, 453-466

Berger, Philip E. (1993). “Explicit and Implicit Tax Effects of the R&D Tax Credit”. *Journal of Accounting Research*, 31(2), 131-171.

Bernstein, Jeffrey I. and Nadiri, I. (1989). “Research and Development and Intra-Industry Spillovers: An Empirical Application of Dynamics Duality”. *The Review of Economic Studies*, 56(2), 249-267.

Bloom, N., R. Griffith and J. Van Reenen (2002). “Do R&D Tax Credits Work? Evidence from a Panel of Countries 1979-1997”. *Journal of Public Economics*, 85, 1-31.

Cohen, Wesley M. and Klepper, S. (1992). “The Anatomy of Industry R&D Intensity Distributions”. *The American Economic Review* 82(4), 773-799.

Cohen, Wesley M. and Levinthal, D.A. (1989). “Innovation and Learning: The Two Faces of R&D”, *Economic Journal*, 99(337), 569-596.

Davis, S. J., J. C. Haltiwanger and S. Schuh. (1997) “Job Creation and Destruction”, Cambridge, Mass.: MIT Press.

Dunne, T., M. Roberts and L. Samuelson (1989). “The Growth and Failure of U.S. Manufacturing Plants”. *Quarterly Journal of Economics* 104, 671-698.

Eisner, R., S. H. Albert and M. Sullivian (1984). “The New Incremental Tax Credit for R&D: Incentive or Disincentive?”. *National Tax Journal*, 37, 171-183.

Bronwyn, Hall H. (1993) “R&D Tax Policy During The 1980’s: Success or Failure?”, in J.M. Poterba, ed., *Tax Policy and the Economy* NBER ,7, 1-35.

Bronwyn, Hall H. and Van Reenen, J. (2000). “How Effective are Fiscal Incentives for R&D? A Review of the Evidence”. *Research Policy*, 29, 449-469.

Hopenhayn, H.A. (1992). “Entry, Exit and Firm Dynamics in the Long Run Equilibrium”. *Econometrica* 60 (5), 1127-1150

Hopenhayn, H.A. and Rogerson, R. (1993).“Job Turnover and Policy Evaluation: A General Equilibrium Analysis”. *Journal of Political Economy* 101(5),915-938.

Mansfield, Edwin (1986). “The R&D Tax Credit and Other Technology Policy Issues”. *American Economic Review* 76, 190-194

Reinganum, Jennifer F. (1981). “Dynamic Games of Innovation”. *Journal of Economic Theory*, 25, 21-41.

Spence, Michael (1984). “Cost Reduction, Competition and Industry Performance”. *Econometrica* 52(1), 101-122.

Veracierto, Marcelo (2000).“Employment Flows, Capital Mobility and Policy Analysis’, *International Economic Review*, 42(3), 571-595.

A Appendix

A.1 Growth Rate Test

In this Appendix, we test whether R&D performing firms grow faster than non-R&D firms. Large literature on firm dynamics suggest that firm size and growth rate are negatively related. Since, average R&D firm size is large, it is expected that on average R&D firms should grow slowly than non R&D firms. However the data suggest quite opposite. Average growth rate of R&D firms is significantly greater than average growth rate of non-R&D firms.

$$H_0 : \mu_R = \mu_{NR}$$
$$H_A : \mu_R > \mu_{NR}$$

Table 1: ***Hypothesis test***

	N	Mean	StDev	Mean Employment	t-value	P-value
R&D Firms	9330	0.0387	0.3516	15501	8.1104	0
Non R&D Firms	6887	0.0078	0.2644	6148		

Compustat Data for 1970-1981 years. N is number of observations. Growth rates are difference of log employment between period t+1 and t. Mean is the average growth rate. StDev is the standard deviation of growth rates. Mean employment is the average employment size in both samples.

A.2 Mean and Variance of Growth Rate

For our specification of productivity process, expected growth rate is

$$E(\frac{m'-m}{m}) = \int_{\underline{m}}^{\infty} \frac{m'}{m} \frac{e^{-|\frac{m'}{h(m,r,R)}-\mu|\sigma}}{2} \frac{\sigma}{h(m,r,R)} dm' - 1$$

By integration by parts, we get

$$E(\frac{m'-m}{m}) = \frac{1}{m}[\mu h(m,r,R) - (\underline{m} - \frac{h(m,r,R)}{\sigma})\frac{e^{-|\frac{\underline{m}}{h(m,r,R)}-\mu|\sigma}}{2}] - 1$$

Differentiating this expression with respect to r and suppressing arguments in h we get

$$\frac{1}{m}[\mu h_r + (\frac{1}{\sigma} - \frac{\underline{m}}{h} + \frac{\underline{m}^2\sigma}{h^2})h_r \frac{e^{-|\frac{\underline{m}}{h}-\mu|\sigma}}{2}]$$

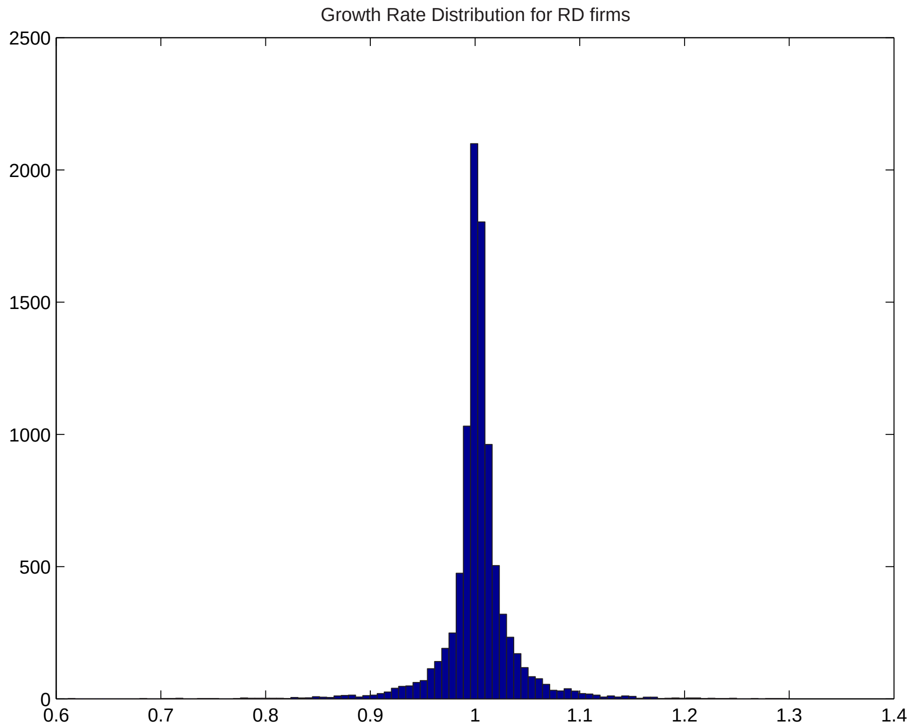

Figure 1: Growth Rates Distribution-Data

Since $\frac{m}{h} - \mu < 0$ and $h_r > 0$ we get that the above expression is greater than zero. Therefore, among firms of equal size ones with higher level of R&D investment grow faster.

Similarly, it can be shown that the variance of growth rate is

$$\frac{1}{m^2}[\frac{2h^2}{\sigma^2} + ((\frac{h}{\sigma} - \underline{m})\frac{e^{-|\frac{m}{h}-\mu|\sigma}}{2})^2 - (\mu + \frac{1}{\sigma})(\frac{h}{\sigma} - \underline{m})e^{-|\frac{m}{h}-\mu|\sigma}]$$

and it is straightforward to show that this expression is increasing in r. Therefore, if firm decides to increase its R&D investment both it expected growth rate and its variance increases

A.3 Results for Benchmark Economy

In a benchmark economy $\tau = 0$ and r is no longer is a state variable. For a special case with no externality effect from R&D activities, i.e $a = 0$, and for $\underline{m} = 0$ the following holds

Proposition 2 *In an economy without R&D externality and for* $\underline{m} = 0$*, firm R&D investment is linear in* m*.*

Proof. Guess that value function is linear in m, $V(m) = Bm$. Substituting this into the RHS of Bellman equation we get

$$V(m) = \max_{r' \geq 0}\{-r' + \pi^*(m) + Bzm^{1-\gamma}r'^{\gamma}(\mu + \frac{e^{-\mu\sigma}}{2\sigma})\}$$

Differentiating with respect to r', we get the following FOC

$$1 = Bz\gamma(\frac{m}{r'})^{1-\gamma}(\mu + \frac{e^{-\mu\sigma}}{2\sigma})$$

Hence, r' is linear in m. Substituting r' back into the Bellman equation, we can verify linearity of the value function and solve for the value of B. However it should be noted that B is not unique, but under the appropriate assumption about the parameters and imposing bounds on values that R&D intensity, $\frac{r'}{m}$, may take, the uniqueness of B can be delivered. ■

If there is no externality from R&D investments, every active firm will perform an R&D activity and firm's R&D intensity, which is R&D investment over the sale, will be constant across firms. However, this result is not useful for two main reasons[14]. Although, in the data there is no relationship between R&D intensity and firm size, the distribution of R&D intensity is non-degenerate as well. Figure 4 shows R&D intensity distribution for Compustat firms[15]. Second, more important for our purpose, not every firm is involved in R&D activity. Quite opposite, very few firms are active R&D performers. Introduction of externality effect can to some degree capture this aspect of data.

Proposition 3 *V is increasing in* m *and* R

Proof. For non R&D firms standard dynamic programming techniques are applied. For R&D firms, let r_1^* be the optimal R&D investment of a firm with

[14]Since in the model firm sale (output) is proportional to its size, R&D over the firm size is also constant

[15]Similar results for R&D intensity distribution was obtained by Cohen and Klepper (1992) using Business Line data

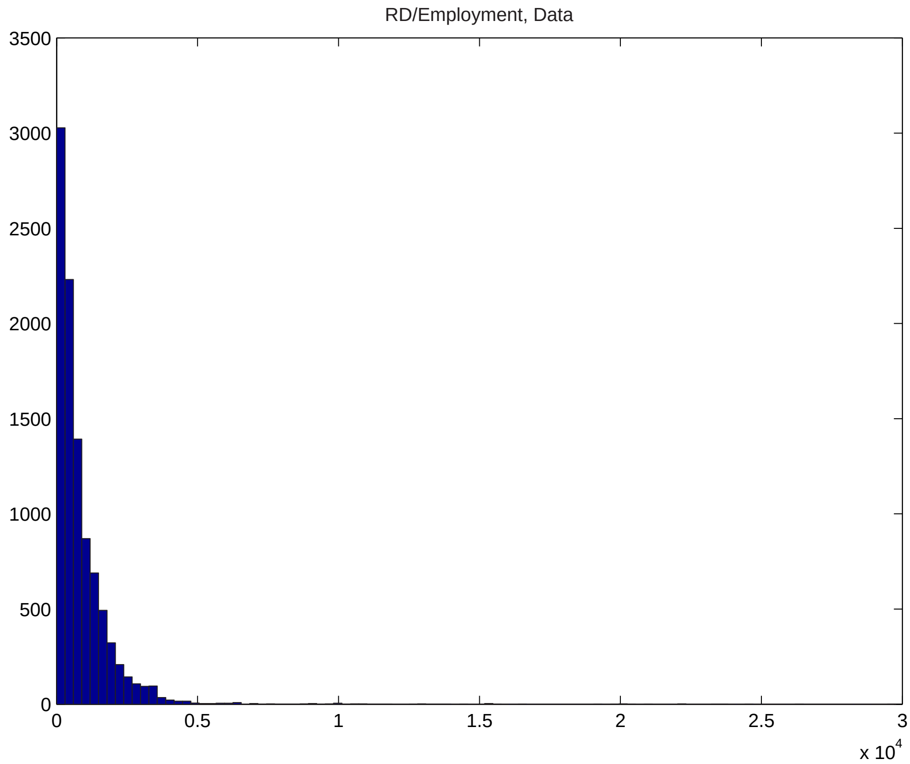

Figure 2: R&D Intensity Distribution-Data

productivity m_1. Then for any firm with productivity $m_2 > m_1$, if possible, the firm can choose r_2 such that $h(m_2, r_2; R) = h(m_1, r_1^*; R)$, so that the continuation profit for both firms are the same. Since, $m_2 > m_1$ then $r_2 < r_1^*$, implying that

$$V(m_2; R) \geq -r_2 + \pi^*(m_2) + \beta \int_{\underline{m}}^{\infty} V(m'; R) \frac{e^{-|\frac{m'}{h(m_2, r_2, R)} - \mu|\sigma}}{2} \frac{\sigma}{h(m_2, r_2, R)} >$$

$$> -r_1^* + \pi^*(m_1) + \beta \int_{\underline{m}}^{\infty} V(m'; R) \frac{e^{-|\frac{m'}{h(m_1, r_1^*, R)} - \mu|\sigma}}{2} \frac{\sigma}{h(m_1, r_1^*, R)} = V(m_1; R)$$

If there is no r_2 satisfying $h(m_2, r_2; R) = h(m_1, r_1^*; R)$, then firm can choose r_2=0. Then, $h(m_2, 0; R) > h(m_1, r_1^*; R) = h(m_1', 0; R)$, where, $m_1 < m_1' < m_2$. Therefore,

$$V(m_2; R) \geq \pi^*(m_2) + \beta \int_{\underline{m}}^{\infty} V(m'; R) \frac{e^{-|\frac{m'}{h(m_2, 0, R)} - \mu|\sigma}}{2} \frac{\sigma}{h(m_2, 0, R)} >$$

$$> -r_1^* + \pi^*(m_1) + \beta \int_{\underline{m}}^{\infty} V(m'; R) \frac{e^{-|\frac{m'}{h(m_1', 0, R)} - \mu|\sigma}}{2} \frac{\sigma}{h(m_1', 0, R)} = V(m_1; R)$$

Similarly, it can be shown that V is increasing in R. ■

Let $G(m, R, m')$ be the Markov process associated with the optimal R&D decision. Then,

$$G(m, R, ; w) = \begin{cases} F(m, 0, R, m'), & if \;\; r'(m) = 0 \\ F(m, r'(m), R, m'), & if \;\; r'(m) > 0 \end{cases}$$

If we can show that $G(m, R, m')$ is decreasing in m, then our environment will be reduced to Hopenhayn (1992) environment. The sufficient condition for that is monotonicity of the R&D decision rule. However, with our specification it is not possible to show that r' is nondecreasing in m. To see why it is the case lets combine FOC and Envelope condition from firm's problem

$$V'(m; w, R) = \pi'^{*}(m) + (\frac{r' + aR}{m})(\frac{1-\gamma}{\gamma}) + \phi$$

where ϕ is a Lagrange multiplier on $r' \geq 0$ constraint. For $r' > 0$, R&D investment level is implicitly defined by

$$r'(m) = (V'(m; w, R) - \pi'^{*}(m))m(\frac{\gamma}{1-\gamma}) - aR$$

and it is not clear whether $(V'(m; w, R) - \pi'^{*}(m))m$ is increasing in m or not. Fortunately, for the model parametrization in the calibration section it turns out that r' is nondecreasing in m.

A.4 Tables/Figures

Table 2: ***Parameters***

a	$log(z)$	γ	μ	σ	υ
3.7659	0.2804	0.986	1.0166	0.4502	0.1018

Table 3: ***Moments***

	Source	Data	Model
Fraction of nonRD firms	NSF	95.35 %	94.18 %
Average of JC and JD Rates	Davis et. al	21.1880 %	20.3840%
Exit Rate	Dunne et.al.	8.6 %	8.76 %
Average Firm Size	Enterprise Statistics	68.551	68.551
Std of Firm Size	Enterprise Statistics	1143	1037
Job Creation due to birth	Davis et. al	1.3712 %	1.3192 %

Job Creation (Destruction) at time t equals employment gains (losses) summed over all firms that expand (contract) or start up (shut down) between period t-1 and t, divided by the average employment level. Average quarterly Job Creation (Destruction) Rate between 1973-1981 is 5.1152 (5.479). Average quarterly Job Creation due to birth is 0.3428 %. Five-year exit rate is 36.2%.

Table 4: ***Employment Distribution***

Employment Size	Data	Model
1-19	70.4361	70.1966
20-99	22.7705	22.8004
100-499	5.4743	5.5579
500-2499	0.9872	1.1490
2500-4999	0.1408	0.1432
5000-9999	0.0800	0.0823
10000 over	0.0921	0.0706

Source: Enterprise Statistics 1963,1967,1972,1977,1982

Table 5 ***R&D Distribution by Firm Size***

Employment Size	Data	Model
1-499	0.1634	0.1404
500-4999	0.2115	0.3961
5000-10000	0.2007	0.1228
10000 over	0.4244	0.3406

Source: NSF 1970-1981

Table 6: ***Moments for R&D firms***

Moments	Data	Model
Average R&D firm size	929.39	903.05
Fraction of Employment in R&D firms	0.6912	0.7667
Average R&D Growth Rate	0.1251	0.0913
Variance of R&D Growth Rate	0.3227	0.3852
Average Employment Growth Rate, R&D firms	0.064	0.0739
Corr (log(r'),log(r))	0.9854	0.9246
Corr (log(n),log(r))	0.8721	0.9873
Corr (log(n'),log(n))	0.9954	0.9312

Average R&D firm size and Fraction of Employment in R&D firms are from NSF and Enterprise Statistics. The rest of the moments are from Compustat datafile

Table 7: ***Results***

	No Policy $\tau = 0$	Optimal Policy $\tau = 0.038$	Current Policy $\tau = 0.2$
Increase in Average R&D	0	4380 \$	22940 \$
Tax Credit per firm	0	2335 \$	15158 \$
Consumption	100	99.993	100.061
Output	100	99.852	100.748
Net Output	100	99.668	99.5891
Wage	100	99.994	100.058
Average Firm Size	68.551	69.228	69.960
Total Employment	100	99.850	100.675
Average Productivity	100	100.143	99.236
Welfare %	0	0.00682	-0.00684

Net Output is the difference between Total Output and Total R&D investment.
R&D statistics are in 1992 constant dollars.

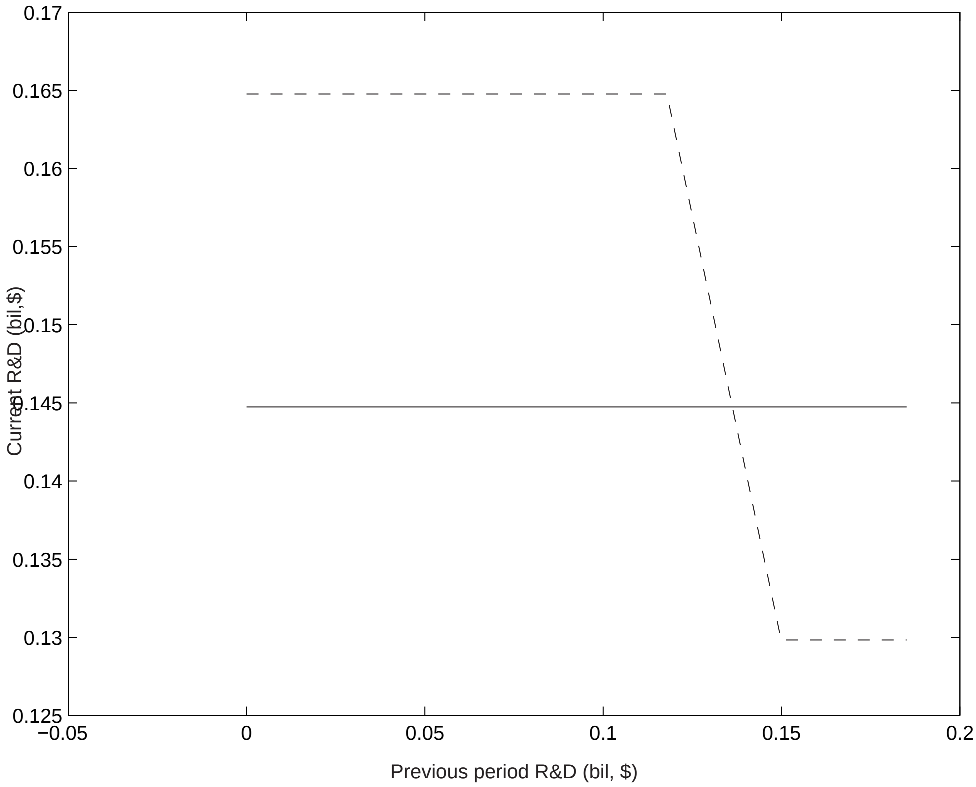

Figure 3: R&D Decision Rules

Table 8: ***Moments***

Moments	τ=0	τ=0.038	τ=0.2
Average R&D firm size	903.0539	904.931	905.1356
Percentage of R&D firms, %	5.82	5.88	5.95
Fraction of Employment in R&D firms	0.7667	0.7682	0.7699
Average R&D Growth Rate	0.0913	0.0938	0.2183
Variance of R&D Growth Rate	0.3852	0.4017	0.5032
Average Employment Growth Rate, R&D firms	0.0739	0.0742	0.0756
Variance of Employment Growth Rate, R&D firms	0.3831	0.3846	0.3843
Corr (log(r'),log(r))	0.9246	0.9211	0.8985
Corr (log(n),log(r))	0.9873	0.9874	0.9843
Corr (log(n'),log(n))	0.9312	0.9308	0.9303
Average Employment Growth Rate, all firms	0.0743	0.0746	0.0761
Variance of Employment Growth Rate, all firms	0.4293	0.4307	0.4305
Corr (log(n'),log(n)), all firms	0.9583	0.9581	0.9579

Growth Rate is defined as $\frac{S_{t+1}-S_t}{S_t}$, *where S variable is either R&D, r, or Employment Size, n.*

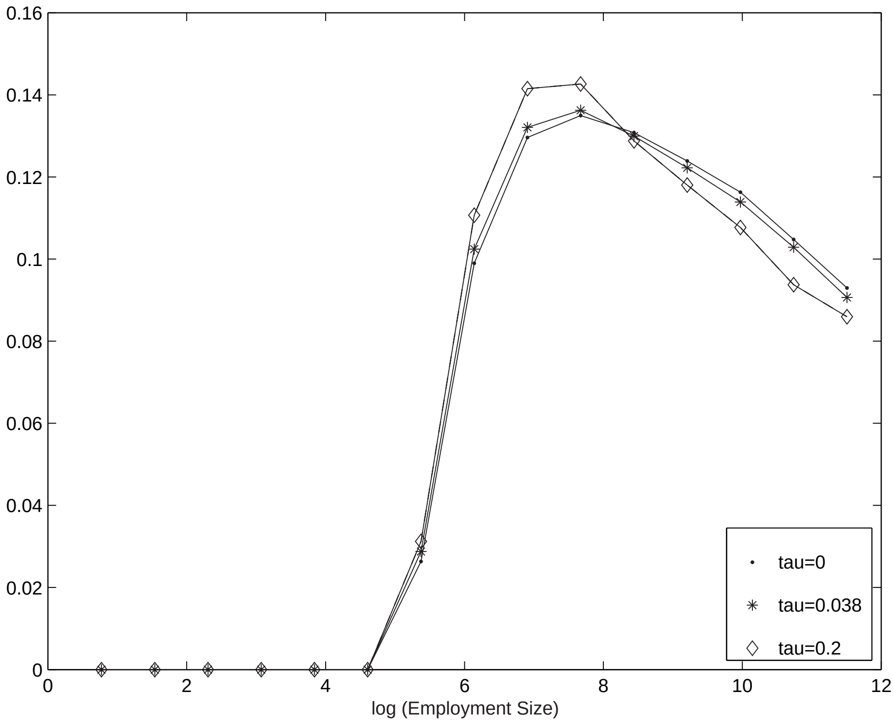

Figure 4: R&D Distribution by Firm Size