On the Aggregate and Distributional Effects of Innovation Policies*

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Extended Abstract

To promote economic growth led by technology improvement, many governments around the world subsidize business research and development (R&D). Although many papers have studied the effectiveness of these subsidies on firms,[1] little is known about the distributional effect of R&D subsidies on households that differ in occupation, productivity, and wealth. To study this question, we build a heterogeneous-agent model featuring occupational choice, endogenous innovation, and financial frictions. The occupational choice to become an entrepreneur leads to endogenous entry of pass-through entities. Different from C-corporations, pass-through entities face financial frictions. As a result, pass-through entities at top productivity levels largely underinvest in R&D compared to C-corporations. (Figure 2(A))

We then ask whether governments can improve welfare by correcting the underinvestment in R&D with fiscal policies. First, we study the optimal uniform subsidy, which incentives pass-through entities at all productivity levels to increase R&D. (Figure 2(C)) Top productivity entrepreneurs, who are also the wealthiest households, are the biggest losers of this policy. This is because equilibrium wage increase resulting from higher productivity, and for the same reason, all workers are winners of this policy. (Table 4)

Next, we propose a non-linear R&D subsidy policy in which only pass-through entities above a productivity cutoff receive the R&D subsidy. This non-linear R&D subsidy is more effective in correcting the underinvestment of R&D in pass-through entities. (Figure 2(D)) This is because unlike the uniform subsidy, the non-linear subsidy targets the most productive firms, whose R&D

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[1] For theoretical analysis, see Acemoglu et al. (2018), Akcigit, Hanley, and Stantcheva (2016), and Akcigit, Hanley, and Serrano-Velarde (2021). For empirical estimates, see Wilson (2009), Brown, Fazzari, and Petersen (2009), Dechezleprêtre et al. (2016), and Howell (2017) for examples.

investment are most constrained by financial frictions. As a result, the increase in welfare under this non-linear subsidy policy is larger than the uniform subsidy policy. In terms of the distributional effect, the optimal non-linear subsidy increases income and wealth concentration, because it disproportionately benefits the most productive entrepreneurs, who are at the top of the income and wealth distribution. ((Table 4))

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Appendices

A Model

In this section, we first describe the model environment in Section A.1, where we specify our assumptions, and then describe the optimization problems for C-corporations and entrepreneurs of pass-through entities in Section A.2 and Section A.3.

A.1 Environment

Demographics. We consider an economy with a continuum of individual households of measure one. In each period, individuals choose between the two occupations: worker or entrepreneur, and therefore the fraction of entrepreneurs is endogenous. The lifespan of both types of households is infinite. Each entrepreneur runs a pass-through entity and earns business income from the firm's profit Labor market is competitive. Workers supply labor either to a pass-through entity (E) or to a C-corporation (C).

Preference. Each household maximizes its discounted stream of utilities by choosing consumption c_t in each period. The household's objective function is given by:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma} \right\}$$

where $\beta \in (0,1)$ is the discount factor and the expectation operator is with respect to all future idiosyncratic shocks.

Labor Productivity. The labor productivity e of households follows an AR(1) process given by

$$log(e') = \rho_e log(e) + \epsilon_e$$

where ρ_e is the annual persistence of the autoregressive process and $\epsilon_e \sim N(0, \sigma_e)$ is i.i.d. across all households.

Innovation. We use z to represent the entrepreneurial productivity as well as the productivity of C-corporations. The stochastic process is endogenously determined by the choice of R&D investment. We assume that productivity grid points are unevenly distributed over the interval $[z_{min}, z_{max}]$. Let j indexes the j_{th} grid point of productivity, then we have

$$z_j = \left[z_{min}^{\Gamma} + \frac{z_{max}^{\Gamma} - z_{min}^{\Gamma}}{N_z - 1} \times (j-1) \right]^{\frac{1}{\Gamma}}$$

where N_z, the total number of productivity grid points, and Γ, controls the distribution of z. We assume $\Gamma > 1$ to ensure that the grid space is denser at the top of the distribution. This feature helps us match the firm size distribution in US.

Firms use a R&D technology that yields a probability p of a technology upgrade (and probability $1-p$ of a downgrade) by one step in return to investing $\chi(p,z)$ units of consumption good. The cost of innovation takes the following form:

$$\chi(p,z) = z\mu(e^{\phi p} - 1)$$

where μ is a scale parameter and ϕ is a the elasticity parameter. We assume the innovation cost is linear in a firm's current productivity and convex in the upgrading probability.

Production. There are two sectors of firms in the production market: pass-through entities owned by entrepreneurs and C-corporations owned by public. We index them by $i \in \{E, C\}$.

Firms have access to a decreasing-returns-to-scale production technology that combines two factors of inputs: labor l and capital k. The production function takes a standard Cobb-Douglas form given by

$$f(z,k,l) = z(k^{\alpha} l^{1-\alpha})^{\gamma_i}$$

where γ is the span-of-control parameter. A share, γ, of output goes to factors of inputs. Out of this, a fraction of α goes to capital and α goes to labor. The output of production is a homogeneous final good, whose competitive price is the numéraire of the economy. We allow the return-to-scale parameter γ to vary across sectors.

Financial market. There is a financial market where intra-period borrowing and lending take place at a risk-free rate of r. Entrepreneurs borrow to finance their capital demand and R&D expenditures. We assume that borrowing decisions take place after z is observed, so there is no risk of default. Moreover, entrepreneurs must rent capital and invest in R&D before revenues are realized. As a result, the maximum amount of intra-period loan is constrained by the wealth of entrepreneurs. The collateral constraint is given by

$$k + (1 - \tau_{\chi}\mathbb{I}_{\chi}(z))\chi(p,z) \leq \lambda a$$

where τ_{χ} is the government subsidy on innovation cost and $\mathbb{I}_{\chi}(z)$ is a indicator function determining a firm's eligibility of R&D subsidy.

We assume that C-corporations are not subject to the collateral constraint when choosing their capital and R&D expenditures.

Tax system. The government finances its expenditure on R&D subsidies and other spending, G, through four tax instruments. Specifically, all households are subject to a non-linear personal income tax levied according to the tax schedule $T(\cdot)$ based on their business or labor income. The income tax function takes the following form

$$T(y) = y - \lambda_y y^{1-\tau_y}$$

which is proposed by Benabou (2002) and used also by Heathcote, Storesletten, and Violante (2017). The parameter τ_y determines the degree of progressiveness of the tax system and the second parameter, λ_y, determines the average level of taxation in the economy. In addition, households are subject to a linear consumption tax τ_s and dividend tax τ_d.

The government also imposes a flat-rate corporate income tax, τ_c, on the profits of C-corporations. Pass-through entities do not pay the corporate income tax, as their business profits pass through to their owners income, and subject to income tax, as pointed out by Dyrda and Pugsley (2018).

A.2 C-corporations

Timing. At the beginning of each period, an exogenous measure M of potential entrants of C-corporations decide whether to enter the market based on their initial productivity draw z. Upon entering the market, they become incumbent firms and choose capital and labor for production and investment in R&D for technology improvement. From the next period on, incumbent firms also choose whether to exit the market after observing their new productivity draws. Due to the endogenous entry and exit decisions, the firm measure of C-corporations is endogenous.

Entry and exit. Let $v^c(z)$ be the value of a C-corporation with productivity z. Both entry and exit decisions are characterized by

$$V(z) = max\left\{v^C(z), 0\right\}$$

where 0 is the cut-off value, below which firms will not enter the market or choose to exit the market.

Optimization problem. We assume that to continue their businesses, C-corporations have to pay a fixed operation cost, κ, in every period. Then, conditional on choosing to continue, C-corporations solve the following recursive problem:

$$v^C(z) = \underset{P}{max}\left\{d(z) + \frac{1}{1+(1-\tau_d)r}\left[PV(z^+) + (1-P)V(z^-)\right]\right\}$$

subject to

$$d(z) = (1-\tau_c)\left(\underset{k,l}{max}\left\{z(k^\alpha l^{1-\alpha})^{\gamma_C} - wl - (r+\delta)k\right\} - \kappa - (1-\tau_\chi \mathbb{I}_\chi(z))\chi(P,z)\right)$$

and

$$d(z) \geq 0, k \geq 0, l \geq 0$$

where $d(z)$ is the dividends paid to shareholders, $V(z^+)$ ($V(z^-)$) is the firm value if technology upgrades (downgrades) by one step in the next period

Firms decide on the probability of upgrading, P, to maximize their discounted streams of dividends. The tradeoff is that choosing a larger P can lead to a better chance of upgrading, but also costs more R&D expenditures.

The aggregate after-tax dividends paid to households is given by

$$D = \int d(z)\mu^c$$

where μ^c the distribution of incumbent firms in the corporate sector.

A.3 Households

Timing. First, we describe the timing of households' decisions. At the beginning of every period, households observe their asset, labor productivity, and entrepreneurial productivity. If the household decides to become an entrepreneur, she chooses capital and labor for production, investment in R&D, and savings. Her working productivity will evolve according to a AR(1) process, and the probability of technological upgrading depends on R&D expenditures.

If the household decides to become a worker, then she will only choose how much to save. With probability ψ, her next-period entrepreneurial productivity will downgrade by one step. With probability $1-\psi$, her next-period entrepreneurial productivity will re-draw from a Pareto distribution. The worker's working productivity follows the same AR(1) process.

Occupation choice. We assume that there is no entry cost to start a business. The following discrete-choice problem characterizes the occupation choice problem

$$v(a,e,z) = max\left\{v^E(a,e,z), v^W(a,e,z)\right\}$$

where v^E is value of being a entrepreneur and v^W is the value of being a worker.

Worker problem. Conditional on choosing to become a worker, households solve the following recursive problem

$$v^W(a,e,z) = \max_{c,a'}\left\{\frac{c^{1-\sigma}}{1-\sigma} + \beta\left[\psi\mathbb{E}_{e'}v(a',e',z^-) + (1-\psi)\int \mathbb{E}_{e'}v(a',e',z')G(z')\right]\right\}$$

subject to

$$(1+\tau_s)c + a' = (1+(1-\tau_d)r)a + we + (1-\tau_d)D - T_i(we)$$

and

$$c \geq 0, a' \geq 0$$

where $G(z)$ is the Pareto distribution from which the worker can re-draw their entrepreneurial productivity.

Entrepreneur problem. Conditional on choosing to become a entrepreneur (owner of a pass-through entity), households solve the following recursive problem

$$v^E(a,e,z) = \max_{c,a',p} \left\{ \frac{c^{1-\sigma}}{1-\sigma} + \beta \left[p\mathbb{E}_{e'} v(a',e',z^+) + (1-p)\mathbb{E}_{e'} v(a',e',z^-) \right] \right\}$$

subject to

$$(1+\tau_s)c + a' = (1+(1-\tau_d)r)a + \pi(a,z) + (1-\tau_d)D - T_i(\pi(a,z))$$

and

$$c \geq 0, a' \geq 0$$

where the profit function of a pass-through entity is given by

$$\pi(a,z) = \max_{k,l} \left\{ z(k^\alpha l^{1-\alpha})^{\gamma_E} - wl - (r+\delta)k \right\} - (1+r)(1-\tau_\chi \mathbb{I}_\chi(z))\chi(p,z)$$

subject to

$$k + (1-\tau_\chi \mathbb{I}_\chi(z))\chi(p,z) \leq \lambda a$$

and

$$k \geq 0, l \geq 0$$

A.4 Stationary Equilibrium

Given government tax and subsidy policies $\{\tau_s, \tau_d, \tau_c, \tau_\chi, T_i, G\}$, a stationary recursive competitive equilibrium is a set of value function $\{v^C, v^W, v^E\}$, allocations of C-corporations $X^C = \{d, P, k, l\}$, C-corporation's entry and exit policies, allocation of workers $X^W = \{c, a'\}$, allocation of entrepreneurs $X^E = \{c, a', p, k, l\}$, prices $\{r, w\}$, and distribution of incumbent C-corporations, workers, and entrepreneurs $\mu = \{\mu^c, \mu^w, \mu^e\}$ such that

1. Given prices$\{r, w\}$, allocations X^c, X^W, X^E , and value functions $\{v^C, v^W, v^E\}$ solve the maximization problem descibed above.

2. Capital and labor markets clear:

$$\int a'(a,e,z)d\mu^w + \int a'(a,e,z)d\mu^e = \int k(a,e,z)d\mu^e + \int k(z)d\mu^c$$

$$\int e d\mu^w = \int l(a,e,z)d\mu^e + \int l(z)d\mu^c$$

Parameter		Value
Risk aversion	σ	1.50
Capital share	α	0.36
Span of control, C-corps	γ_c	0.81
Depreciation rate	δ	0.05
Corporate income tax	τ_c	0.28
Dividend tax	τ_d	0.27
Consumption tax	τ_s	0.07
Progressivity of income tax	τ_y	0.07
Average income tax	λ_y	0.74
Persistence of labor productivity	ρ_e	0.90

Table 1: Externally Calibrated Parameters

3. The government budget is balanced:

$$G+\int \tau_\chi \mathbb{I}_\chi(z)\chi(P(z),z)\mu^c+\int \tau_\chi \mathbb{I}_\chi(z)\chi(p(a,e,z),z)\mu^c$$

$$=\int \tau_d ra(a,e,z)d\mu^w+\int \tau_d ra(a,e,z)d\mu^e+\int T_i(we)d\mu^w+\int T_i(\pi(a,z))d\mu^e$$

$$+\int \tau_s c(a,e,z)\mu^w+\int \tau_s c(a,e,z)\mu^e+\int \tau_c\pi^c(z)\mu^c+\tau_d D$$

4. The distribution μ is a fixed point where its transition is consistent with the policy functions and the law of motion for μ:

$$\mu=\Phi(\mu)$$

where Φ is a one-period ahead transition operator such that $\mu'=\Phi(\mu)$.

B Calibration

B.1 Externally Calibrated Parameters

Table 1 presents the subset of parameters that are calibrated externally. The values we assign to these parameters are either standard ones in the literature or can be directly measured from the data.

In particular, the rates of dividend income and corporate income tax are adopted from Dyrda and Pugsley (2018) and the share of the labor income tax is consistent with those used by Boar and Midrigan (2019).

Parameter		Value	Target	Data	Model
Discount factor	β	0.94	Real Interest rate	0.04	0.04
Span of control, pass-through	γ_e	0.83	Share of entrepreneurs	6.50	6.45
Borrowing contraint	λ	2.60	Debt to net worth ratio	0.55	0.56
R&D subsidy rate	τ_χ	0.10	R&D subsidy to GDP	0.21	0.23
Density of productivity grid	Γ	3.50	Top 1% wealth share	0.36	0.36
Scale of R&D cost	μ	0.01	R&D to GDP	2.70	2.34
Elasticity of R&D cost	ϕ	25.5	Top 5% employment share	0.71	0.76
Probability of z redraw	$1-\psi$	0.40	Entry rate of entrepreneur	0.02	0.02
Pareto shape of $G(z)$	ζ	5.10	Entrant relative employment	0.19	0.31
Fixed operation cost	κ	8.60	Output share of C-corprations	0.61	0.58
Std. dev. of e shocks	σ_e	0.35	Std. dev. of log labor earnings	0.80	0.77
Mass of potential entrants	M	8.20	Fraction of C-corporations	0.05	0.04

Table 2: Internally Calibrated Parameters

B.2 Internally Calibrated Parameters

We then present the calibration strategy for the parameters that are determined jointly in equilibrium. We report the values of the remaining 12 parameters, their empirical targets, and respective model-predicted values in Table 2. We choose the set of parameters by minimizing the distance between the moments generated from the model and their empirical counterparts.

In particular, we target the share of entrepreneurs, the fraction of C-corporations and their output share to ensure that the number of pass-through entities, the relative size and number of C-corporations are consistent with the SCF data. We also choose the parameters that controls R&D cost to ensure that R&D to GDP ratio and the size distribution of firms is close to both macro and micro data, respectively. Moreover, we choose the probability of productivity redraw as well as the shape of $G(z)$ to match the entry rate and entrant's relative size in the data.

C Quantitative Results

This section presents the key results in our baseline and counterfactual analysis as well as in our policy experiments.

C.1 Welfare Analysis

In our policy experiments, we define the consumption-equivalent welfare change as the permanent increase in consumption $\Delta(a, e, z)$ that leaves the household indifferent between the stationary

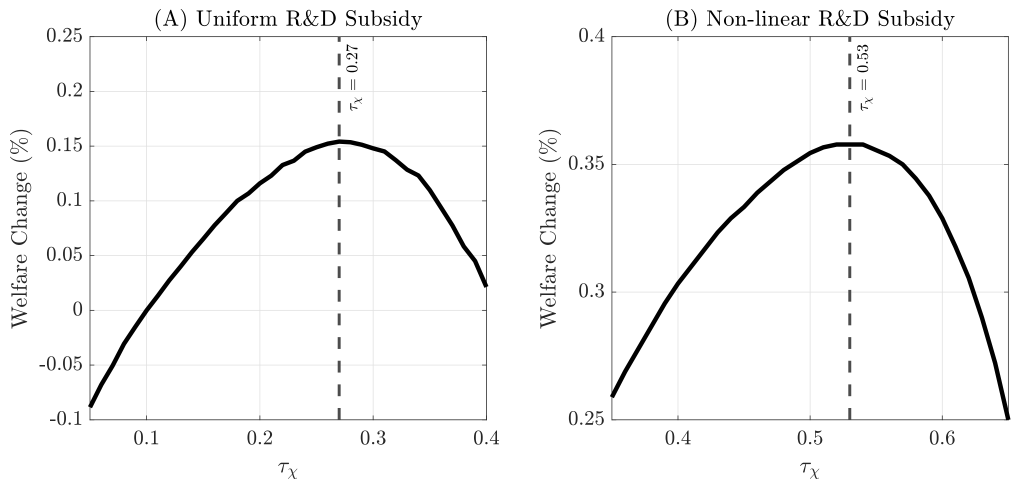

Figure 1: Welfare-Maximizing R&D Subsidy Rates

Panel (A) shows the computation for optimal uniform R&D subsidy. The optimal rate is found to be 27%. Panel (B) shows the computation for optimal non-linear R&D subsidy, in which case only pass-through entities above the technology cutoff is eligible for the subsidy. The optimal subsidy rate is found to be 53%.

equilibrium of the two economies. That is,

$$v[(1+\Delta(a,e,z)) \times c(a,e,z)] = v[\tilde{c}(a,e,z)]$$

where v is the lifetime value function a tilde denotes allocations following the policy change. Given the utility function specified above, we can compute $\Delta(a,e,z)$ directly by

$$1+\Delta(a,e,z) = \left(\frac{v[\tilde{c}(a,e,z)]}{v[c(a,e,z)]}\right)^{\frac{1}{1-\sigma}}.$$

At the aggregate level, the welfare change due to a policy change k can be computed by

$$CE_k = \int \Delta(a,e,z)\mu$$

where μ is the distribution of all households over the three state variables at the initial steady state.

To compute the optimal R&D subsidy policy we maximize CE_k by searching over a large range of τ_χ. That is,

$$\tau_\chi^{best} = \underset{k}{argmax}(\mathrm{C}E_k)$$

where τ_χ^{best} is the optimal policy that leads to the highest welfare gains. Figure 1 plots the welfare functions with respect to the tax rate under the two policies.

C.2 Changes in R&D Expenditures

Figure 2 (A) shows the R&D underinvestment in pass-through entities under our baseline calibration, which is calculated as the difference in R&D expenditures between C-corporations and

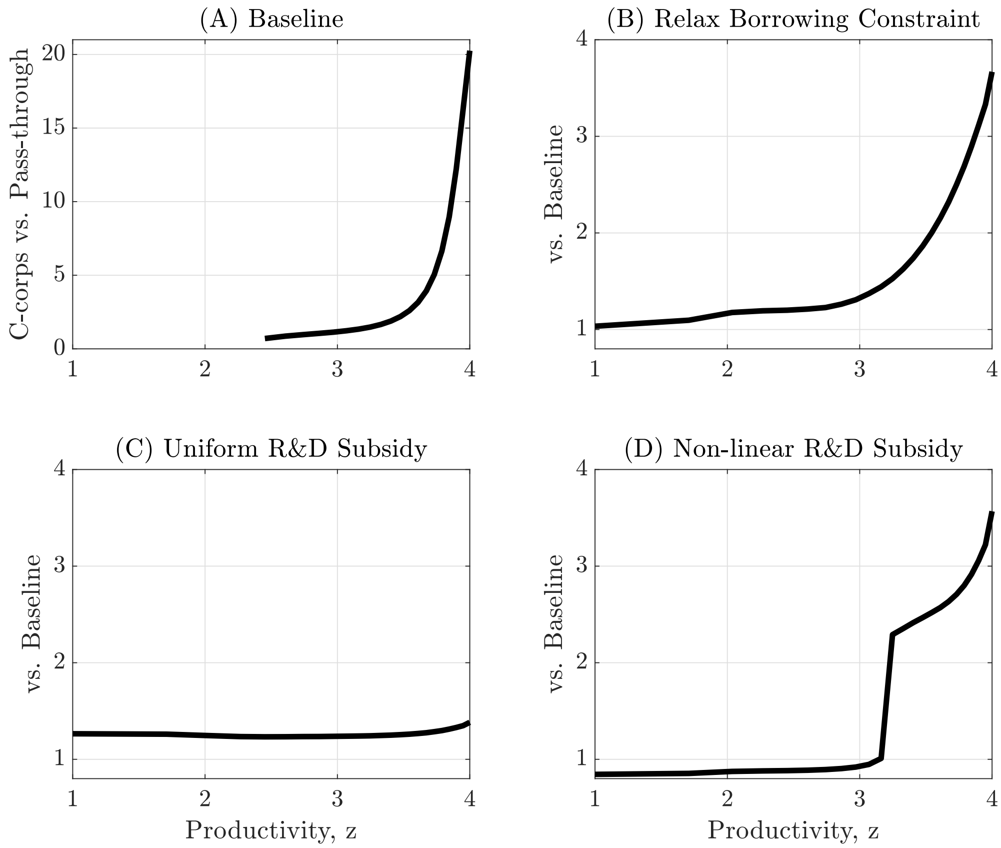

Figure 2: Comparison of R&D Investment

Panel (A) plots the difference in R&D expenditures between C-corporations and pass-through entities averaged across entrepreneurs' wealth levels under our baseline calibration. Panel (B) - (D) plots the rate of change in pass-through entities' R&D expenditures from the baseline case Panel (B) shows the result when the collateral constraint coefficient, λ increases from 2.6 to 5. Panel (C) and Panel (D) show the result under the optimal uniform R&D subsidy and the optimal non-linear R&D subsidy, respectively.

pass-through entities averaged across entrepreneurs' wealth levels. Due to the entry cost for C-corporations, there is a minimum technology cutoff for C-corporations. The gap of R&D investments are the combined results from 1) tax status, 2) financial constraints, 3) scale of production, and 4) diversification of risk.

Figure 2 (B) shows the effects of financial constraints on R&D investments in pass-through entities. Specifically, we counterfactually increase the value of λ in the borrowing constraints from 2.6 to 5. The rate of change in R&D expenditures increases with firm productivity.

Lastly, we show how R&D changes under the two policy experiments in Figure 2 (C) and (D). Under the optimal uniform subsidy, the changes in R&D investments only slightly increase with firm productivity. In contrast, under the optimal non-linear subsidy, the relationship between percentage increase and firm productivity is strongly positive, similar to the changes in the counterfactual case in Figure 2(B).

C.3 Aggregate and Distributional Effects

Table 3 shows the aggregate and distributional effects under the two policies. The increase in welfare is larger under the optimal non-linear subsidy, whereas increase in aggregate output is larger under the optimal uniform subsidy. This is mainly due to the fact that the total costs of R&D subsidy is lower under the non-linear subsidy. As a result, the median average labor income tax reduces under the non-linear subsidy, but increases under the optimal uniform subsidy.

The increase in wage is larger under the optimal uniform subsidy than under the non-linear subsidy. This is because unlike the uniform subsidy in which every entrepreneurs benefit, only the most productive entrepreneurs are better off under the non-linear subsidy. Therefore, the value of being an entrepreneur relative to the value of being a worker is larger under the optimal uniform subsidy, leading to a smaller labor supply and a larger equilibrium wage. For the same reason, the fraction of entrepreneurs increases under the optimal uniform subsidy, but decrease under the optimal non-linear subsidy.

The equilibrium interest rate increases slightly under the optimal uniform subsidy but decreases under the optimal non-linear subsidy. The reason is that under the non-linear subsidy, a larger share of output is produced by pass-through entities, whose demand for capital is subject to financial constraint. Therefore, the reduction in the demand of capital reduces the equilibrium interest rate.

Table 4 shows the changes in welfare for different households. First, as the non-linear subsidy only increases subsidies for high productivity entrepreneurs, the total gains for entrepreneurs are smaller, as shown in both the average welfare gain and the percentage of entrepreneurs that are better off. For the same reason, the most productive entrepreneurs gain while less productive entrepreneurs lose under the optimal non-linear subsidy. In contrast, under uniform subsidy, the top productivity entrepreneurs lose due to the increase in higher equilibrium wage. Since the top productivity entrepreneurs are also at the top of the wealth distribution, the changes in welfare at different wealth levels are consistent with the welfare changes at productivity levels.

Second, workers benefit more from the non-linear subsidy policy due to the reduction in labor income tax. However, wealthiest workers lose under the non-linear subsidy policy but benefit from the optimal uniform subsidy. The difference is mainly caused by the changes in the equilibrium wage, which increases under the uniform subsidy but decreases under the non-linear subsidy.

	Baseline	Uniform subsidy	Non-linear subsidy
A. Macroeconomic variables			
Δ welfare, %	-	0.15	0.36
Δ output, %	-	1.14	0.80
Δ wage, %	-	1.25	0.43
interest rate, %	4.00	4.01	3.95
Δ total R&D, %	-	27.18	7.23
Δ total R&D subsidy, %	-	243.39	74.31
fraction of entrepreneur, %	6.45	6.60	5.41
corporate output share, %	57.74	56.89	57.05
corporate firm share, %	4.29	4.30	5.11
median average labor tax, %	25.30	25.84	25.04
B. Distributional variables			
top 1% wealth share, %	35.68	35.31	37.56
top 1% income share, %	15.52	15.52	16.39
top 5% firm employment share, %	75.95	75.25	72.96
Gini wealth, all	0.75	0.75	0.76
Gini wealth, entrepreneur	0.80	0.80	0.82
Gini wealth, worker	0.69	0.69	0.70
wealth share of entrepreneurs, %	30.06	32.09	27.81
income share of entrepreneurs, %	17.72	18.15	17.53

Table 3: Effects of R&D Subsidy Polices

Welfare gains, %	Uniform subsidy	Non-linear subsidy
A. Entrepreneurs		
all entrepreneurs	0.02	-0.10
% better off	59.27	46.91
top 0.1% productivity	-1.83	3.62
top 1% productivity	-1.16	2.21
bottom 99% productivity	0.03	-0.12
top 0.001% wealth	-0.46	3.99
top 0.01% wealth	-0.35	2.47
Q1 wealth	0.13	-0.50
Q2 wealth	0.14	-0.15
Q3 wealth	-0.02	0.05
Q4 wealth	-0.18	0.23
B. Workers		
all workers	0.16	0.39
% better off	96.11	97.16
top 0.1% wealth	0.16	-0.66
top 1% wealth	0.23	-0.39
Q1 wealth	0.22	0.17
Q2 wealth	0.17	0.39
Q3 wealth	0.16	0.48
Q4 wealth	0.11	0.51

Table 4: Welfare Changes from R&D Subsidy Polices