Dynamics of Financing Frictions for Investment in R&D[1]

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(2) Can the tax system help?

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This experiment allows the estimation of both the **extent of financing constraints**, and the **effectiveness of tax incentives for cash constrained firms** using a structural model.

This Paper

1. Use administrative data on the population of tax returns matched with FAME to analyse the **relationship between financing constraints and investment**.

2. Build and estimate **a structural model to pin down the mechanisms** underlying heterogeneous responses to policy.

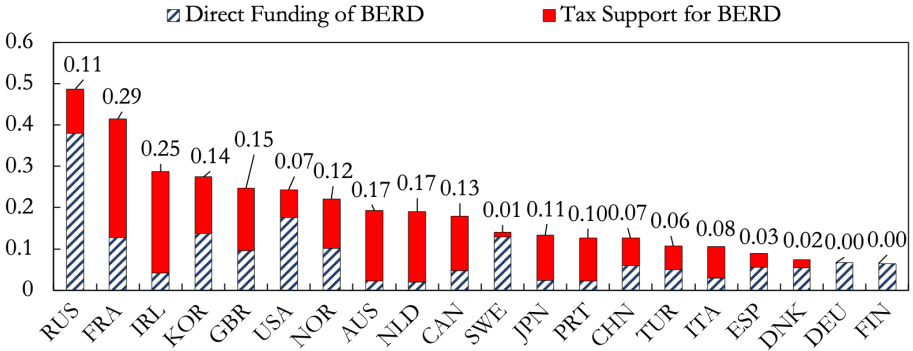
3. Provide **reduced form evidence from a natural experiment** which varied the incentive for different sub-groups of companies and over time.

Often, we do not have access to information that might be used as proxies for unlisted companies' financing frictions. This paper aims to reveal the extent of such constraints and discusses the effectiveness of a measure that may alleviate them.

How is the setup different from other studies?

1. Quantify financing frictions for privately-held, innovative firms (pre-/post-2008).
2. Focus on knowledge capital.
3. The availability of population data (Nikolov, Schmid & Steri, 2021 uses Orbis data to explore unlisted firms' financing constraints).
4. The cash-now/cash-later decision varying exogenously across firms and over time.

A large portion of R&D support is through **tax incentives**, making it a good tool to identify impact on financing constraints



Source: OECD R&D Tax Incentive Database. y-axis values as percent of GDP.

Policy setup

The UK launched R&D tax incentives in 2000 and 2002.

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‘Cash later’ is more beneficial than ‘cash now’ in undiscounted terms

Consider an SME that invests £100 and is in loss **in 2006**, then **in 2010**.

Suppose it will **switch to profit with certainty in the following year**.

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Gain from cash today (2006)	Gain from carry forward to claim against tax in 2007
£24	150 × 0.3 = 45 for main rate taxpayers 150 × 0.2 = 30 for taxpayers at the lower rate

Gain from cash today (2010)	Gain from carry forward to claim against tax in 2010
£24.5	175 × 0.26 = 45.5 for main rate taxpayers 175 × 0.21 = 36.75 for taxpayers at the lower rate

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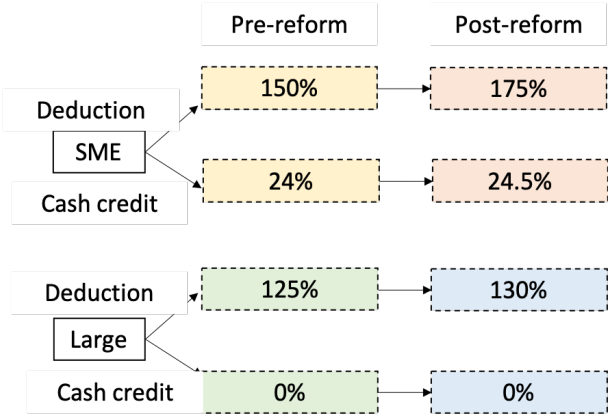
With multiple periods, there are **two reasons to take cash**:
(1) persistent losses, or (2) severe financing constraints.

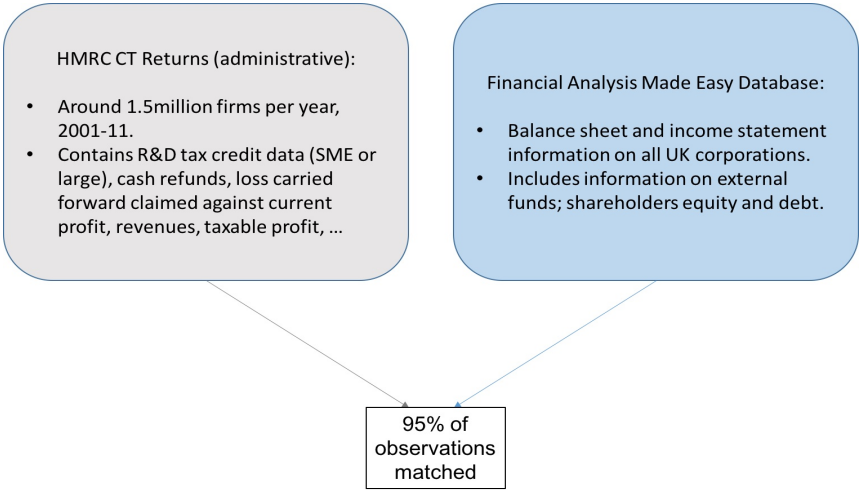
The UK schemes became gradually more generous. The study period covers 4 different policy regimes:



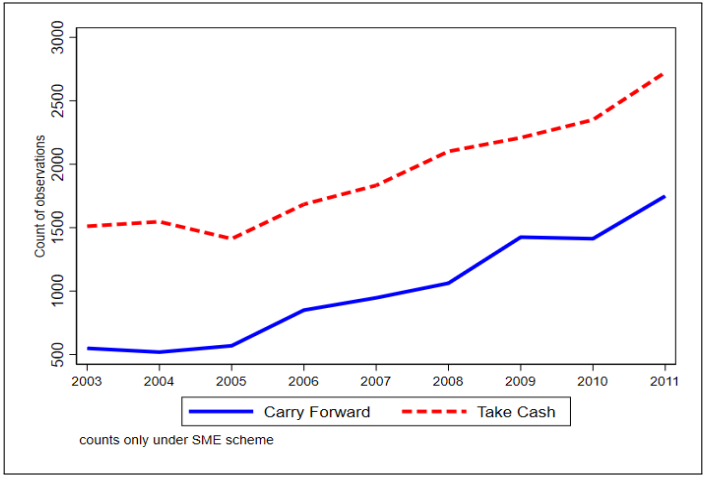
Approach

1. Estimate structural parameters using the pre-reform period.
2. Re-estimate the financing friction in the post-2008 period.
3. Using the model, carry out counterfactual policy simulations.
4. Exploit quasi-experimental variation
   reform 1 was in 2008!
   reform 2 in 2013 provides cash option to large firms.

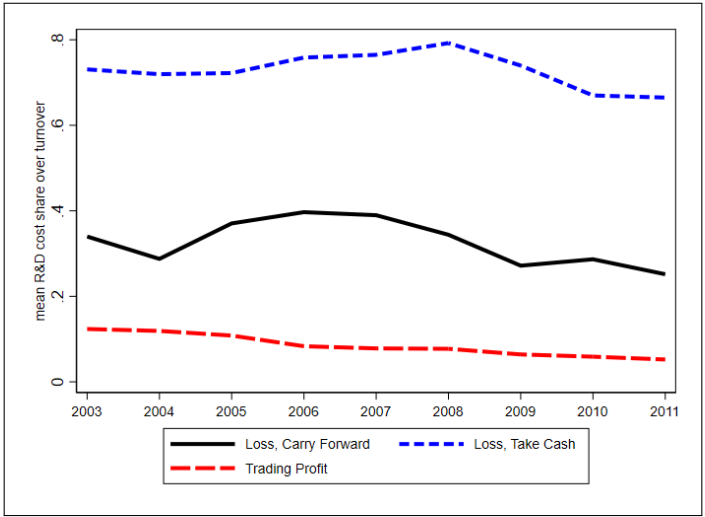
Data


HMRC CT Returns (administrative):
• Around 1.5million firms per year, 2001-11.
• Contains R&D tax credit data (SME or large), cash refunds, loss carried forward claimed against current profit, revenues, taxable profit, …
Financial Analysis Made Easy Database:
• Balance sheet and income statement information on all UK corporations.
• Includes information on external funds; shareholders equity and debt.
95% of observations matched

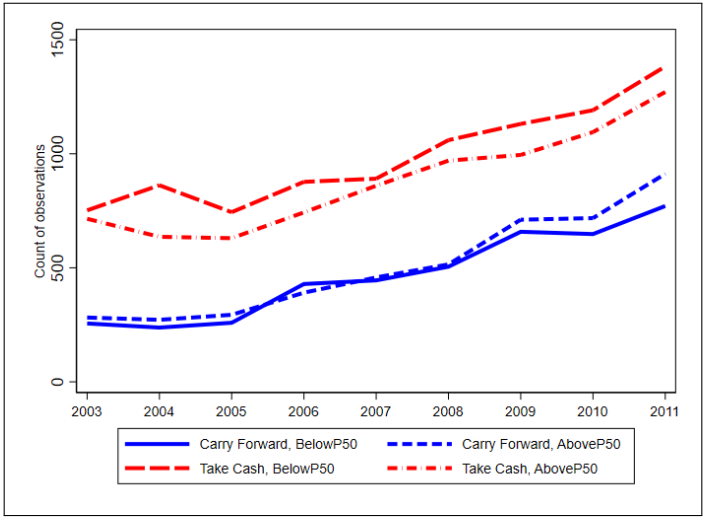
Many companies take the immediate cash option



Profit, loss and the cash decision correlate with R&D intensity



Size (by asset) does not proxy financing constraints



Simple 2-period model

Firms start with $K_0 = 0$ and invest in knowledge capital at $t = 0$.

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At $t = 0$, the firm makes all its decisions about investment and financing. To finance the initial investment K, firms can:

1. take cash ($D = 1$) from the government at rate ϕ and raise the remaining amount by issuing external equity (X), and/or
2. set off this amount against the profit arising in period $t = 1$; $D = 0$, to save on their tax payments. In this case, the firm would have to raise a larger amount of external equity, which entails with it a search cost for the firm, represented by $\Lambda(X)$.

Simple model cont'd

Define the financing friction $\Lambda(X)$:

$$\begin{aligned} \Lambda(X) &= 0 \quad \forall X \leq 0; \\ \Lambda(X) &> 0 \quad \forall X > 0 \end{aligned}$$

The sources and uses of funds:

$$K = X + \phi q K D$$

Rearranging and assuming a linear functional form for $\Lambda(X)$:

$$\begin{aligned} \Lambda(X) &= \lambda X \\ &= \lambda K(1 - \phi q D) \end{aligned}$$

Simple Model: Tradeoff

At $t = 1$, the firm observes the period shock A_1 and starts production. At $t = 0$, the firm maximizes its total payoff π:

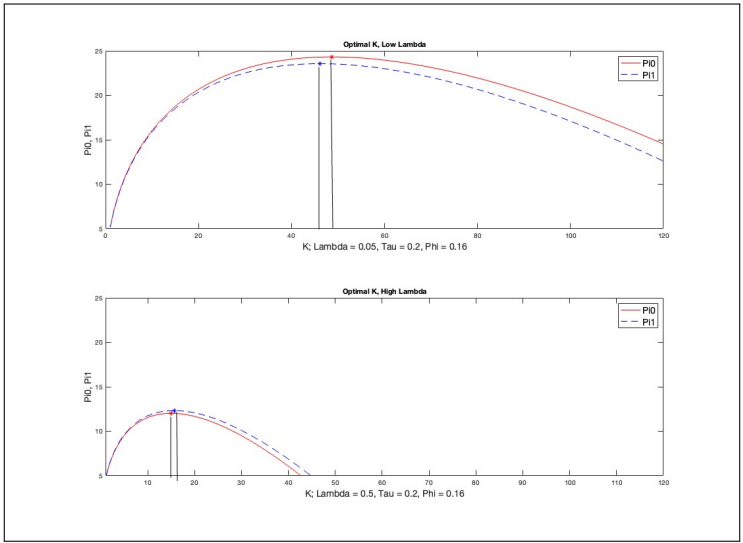
$$\max_{K,D} \left(\mathbb{E}_0[A_1] f(K) - K \right)(1 - \tau) + (1 - D) qK\tau + \phi qKD - \lambda K(1 - \phi qD)$$

Consider the cases in which the firm expects to make a profit at $t = 1$. The firm will choose $D = 1$ if the external financing cost is sufficiently large. In this simple version of the model, the threshold is:

$$\lambda \geq \frac{\tau}{\phi} - 1$$

E.g. for $\tau = 0.2$, $\phi = 0.16$, threshold $\lambda = 0.25$.

Solution: external financing cost of 25% is sufficient to take cash



Time complicates things: what more do we need?

1. Allow firms to **optimise dynamically**.
2. **Incorporate uncertainty** into the firm's current decision-making problem by allowing firms to experience shocks.
3. Reflect the consequences of the **choice between taking the cash option and carrying forward**, in the presence of uncertainty about the future and financing constraints.

Dynamic Stochastic Model of Financial Frictions for R&D

Each firm maximises net present value of all expected future profits:

Firm i's operating profit in period t is:

$$\Omega(K_{it}, R_{it}) = K_{it}^{\alpha_k} \exp(a_i + \varepsilon_{it}) - \underline{G} - R_{it} \qquad \text{(competitive prices)}$$

Each firm decides its investment R_{it} the next period, after the period t shock ε_t is realised.

Law of motion for knowledge capital:

$$K_{it+1} = (1 - \delta_k)K_{it} + R_{it}$$
$$R_{it} > 0 \qquad \text{(Irreversible Investment)}$$

The shock process follows:

$$\varepsilon_{it} = \rho\varepsilon_{it-1} + \nu_{it} \qquad \text{(AR1 process)}$$
$$0 < \rho < 1, \qquad \nu_{it} \sim \mathcal{N}(0, \sigma^2) \qquad \text{(normal i.i.d.)}$$

Introducing taxes

Firms pay taxes on their profit at rate τ.

The government allows R&D to be super-deducted at rate q.

Profit-making firms use the deduction to reduce their tax liability as incurred at period t.

Eligible loss-making firms have two options:

1. Take cash from the government at rate ϕ.
2. Carry the deduction forward to reduce future tax liability as soon as the firm enters profitable position.

The Tax System

The cash flow firm i, after paying taxes, is then:

$$\Pi = \begin{cases} \Omega_{it} - \tau[\Omega_{it} - qR_{it} - M_{it}] & \text{if } \Omega_{it} - qR_{it} \geq 0 \\ \Omega_{it} + D_{it}\phi(1+q)R_{it} & \text{if } \Omega_{it} - qR_{it} < 0 \end{cases}$$

The stock of accumulated carry forwards is:

$$H_{it+1} = \begin{cases} H_{it} - M_{it} & \text{if } \Omega_{it} - qR_{it} \geq 0 \\ H_{it} + (1 - D_{it})[qR_{it} - \Omega_{it}] & \text{if } \Omega_{it} - qR_{it} < 0 \end{cases}$$

and the current period amount carried forward claimed against current profit is:

$$M_{it} = \begin{cases} \min\{H_{it}, \Omega_{it} - qR_{it}\} & \text{if } \Omega_{it} - qR_{it} \geq 0 \\ 0 & \text{if } \Omega_{it} - qR_{it} < 0 \end{cases}$$

Introducing costly external financing

To fund R&D investment, firms can use:

1. period profits (Π_{it}),
2. government cash refund option ($\phi q R_{it}$) if in loss,
3. external equity (X_{it}), with cost $\Lambda(X)$.

The sources and uses of funds in period t can be summarized as follows:

$$X_{it} = -\Pi_{it}$$

Both equity payouts and new equity issuances are captured by X_{it}; with $X_{it} > 0$ indicating new equity issuance and $X_{it} \leq 0$ indicating payouts.

Form of constraint and value maximization

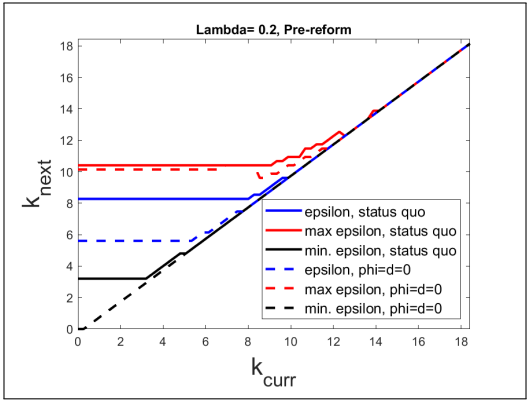
Define external equity flows, Div_{it}, as a distribution to shareholders. Cost of external equity function is assumed to be linear-quadratic and weakly convex.

$$Div_{it} = -[\ \underbrace{X_{it} - \lambda \cdot X_{it} \cdot \mathbf{1}(X_{it} > 0)}_{\text{external equity net of financing cost}}\ ]$$

The firm now maximizes shareholder value, or PDV of all future dividend distributions:

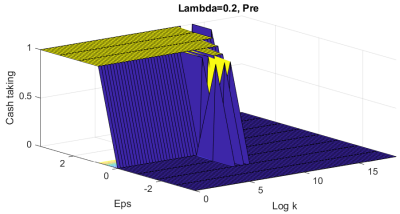
$$V(K_{it}, H_{it}, \varepsilon_{it}) = \max_{K_{it+1}, D_{it}, Div_{it}} \left\{ Div_{it} + \beta \mathbb{E}_t V(K_{it+1}, H_{it+1}, \varepsilon_{it+1}) \right\}$$

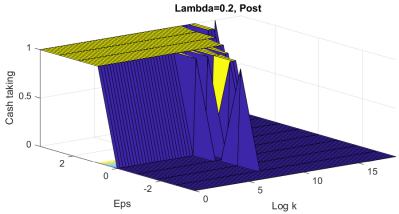
Policy function example: high constraint, investment

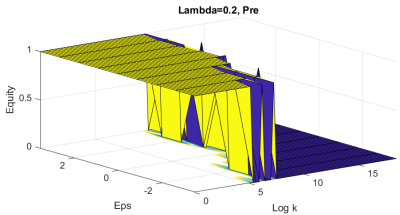


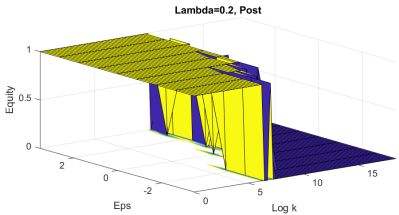
Straight lines: with incentive; red: max(epsilon); blue: min(epsilon)
Dashed lines: without incentive; red: max(epsilon); blue: min(epsilon)

Policy function example: high constraint, Cash & Equity Decisions

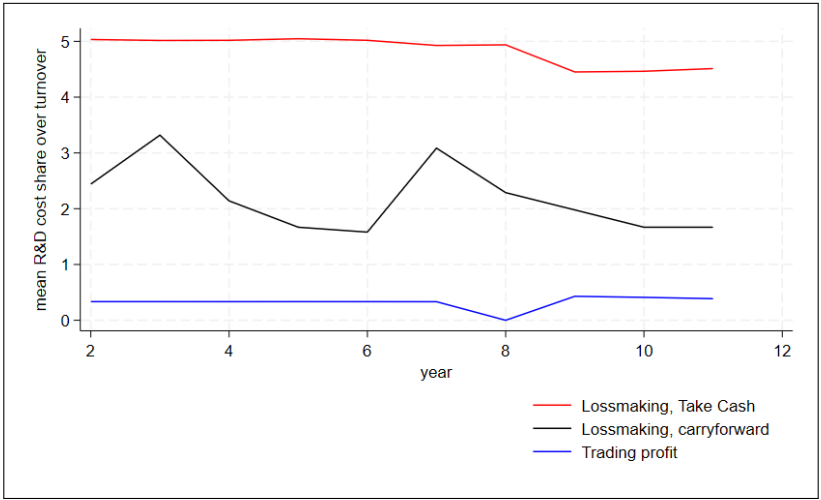




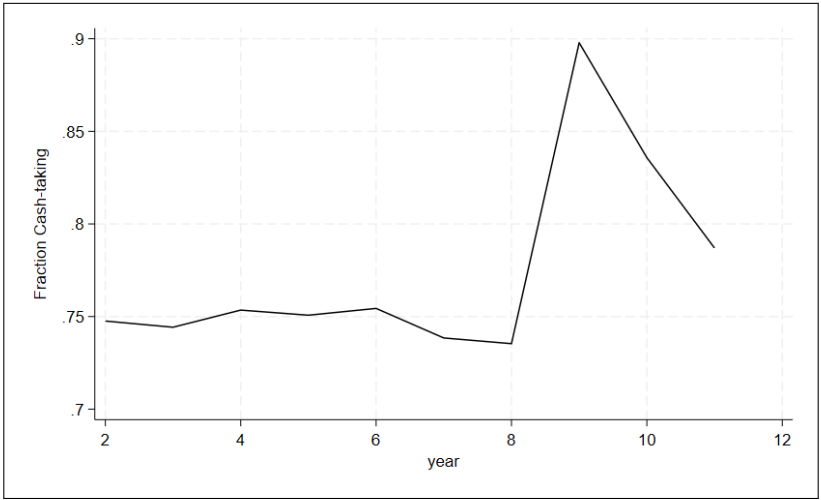




Simulation: R&D Investment



Simulation: Cash-taking



Estimation & Calibration Plan

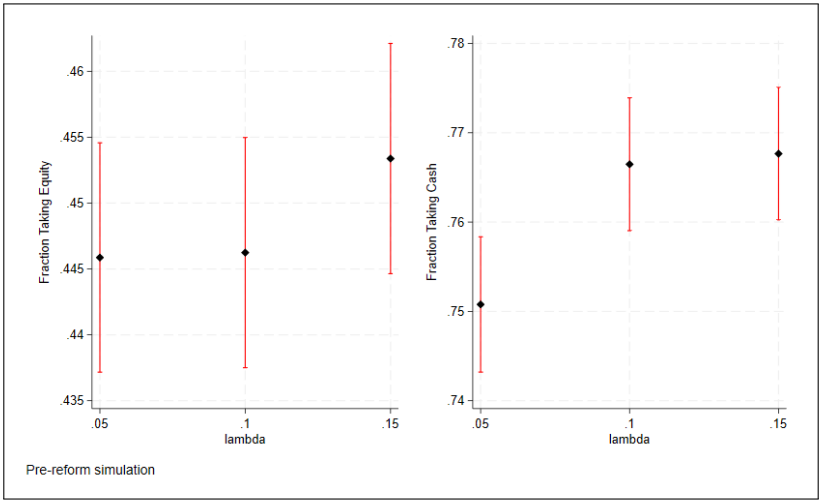
We use **method of simulated moments** (Gourieroux et al., 1993; Gallant and Tauchen, 1996; Smith, 1993) to estimate the parameters related to financing constraints and production function. (An example is Hennessy and Whited, 2007)

We minimise the distance between empirical and simulated moments by choosing the parameter vector and use the bootstrapped variance-covariances as the weight matrix.

We allow permanent unobserved heterogeneity in the technology parameter a, with $a \sim \mathcal{N}(\mu_a, \sigma_a)$.

We provide some reduced form estimates using **difference-in-differences** and provide indicative evidence for financially-constrained firms' differentially higher response to policy reforms.

Varying Lambda, compare simulations



higher lambda $\lambda \implies$ higher fraction of cash-taking firms

Target Moments

1. Identifying λ, separately for pre- and post-2008:
   - Frequency of external finance issuance; median, variance.
   - Share of cash takers in regime.
   - Share of firms with positive taxable profit.
2. Identifying production function parameters σ, ρ, α, μ_a, σ_a:
   - GMM production function estimates.

Parameter estimates (in revision)

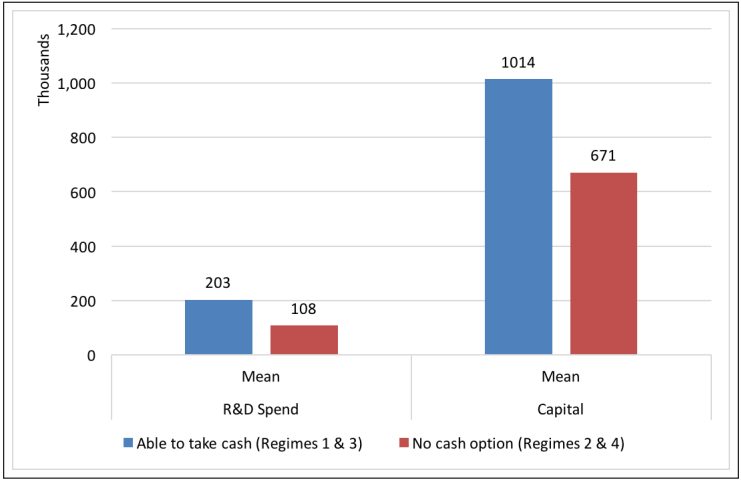
Policy Parameters		
d:	Deduction Rate	$d1 = 0.5$; $d2 = 0.25$; $d3 = 0.75$; $d4 = 0.3$
τ:	Tax Rate	0.2 (for small profits)
ϕ:	Cash refund Rate	$\phi_1 = 0.24$; $\phi_2 = 0.245$

Assumed Parameters		
δ:	Depreciation Rate	0.15 (Hall, Mairesse, Mohnen, 2010)
β:	Discount Factor	0.95 (based on $r_f = 0.05$)

Estimated Parameters		
$\hat{\rho}$:	Persistence Parameter	0.670^{***}
$\hat{\sigma}$:	Variance of the shock term	0.88^{***}
$\hat{\alpha}$:	Elasticity of output wrt R&D	0.694^{***}
$\hat{\lambda}$:	Liquidity constraint	0.14^{***}
$\hat{\mu}_a$:	Average TFP over types	-9.172^{***}
$\hat{\sigma}_a$:	Variance of TFP over types	19.871^{***}

*These earlier results assume Prob$(\lambda_i = \lambda^{High}) = 0.5$ and status assigned permanently.

Policy counterfactual: switch off the cash refund (in revision)



*These earlier results assume Prob($\lambda_i = \lambda^{High}$) $= 0.5$ and status assigned permanently. State space excludes retained earnings.

Conclusion/Next steps

Next steps: Revised estimates and integrating the quasi-experiment in 2008 & 2013 – thoughts welcome!

Applying the model to data, three contributions:

1. **Financing:** Using this framework, it is possible to obtain quantifiable measures of financing frictions for private, innovative companies.
2. **Unobserved heterogeneity:** The framework accounts for heterogeneity in productivity. This is particularly important given diversity of R&D performers and heterogeneous responses to policy support measures.
3. **Counterfactual policies:** After revised estimates, we will test responses to a range of R&D support policies in terms of R&D and innovation performance.

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Other Work:

1. Corporate Responses to Dividend Taxes: An International Perspective (With Steve Bond)
2. Wealth Taxation & Labour Supply: Evidence from the Danish reform
3. Market Power in the Middle East (with Yevgeniya Korniyenko & Weining Xin)
4. German Nationality Reform & Immigrant Human Capital Investments

APPENDIX

What do we already know?

(1) **Financing frictions** explain a large part of firm responses to investment incentives, but they are difficult to measure (Cooper and Ejarque, 2003; Hennessy and Whited, 2007; Strebulaev and Whited, 2012; Hoberg and Maksimovic, 2015; Buehlmaier and Whited, 2018; Nikolov, Schmid and Steri, 2019; 2021. Works on indicators by Fazzari et al., 1988; Kaplan and Zingales, 1997; Whited and Wu, 2006; Farre-Mensa and Ljungqvist, 2016).

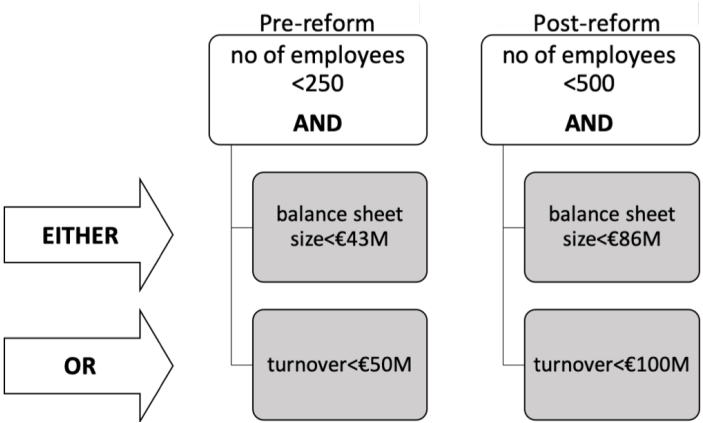
(2) **Financing frictions are particularly steep for R&D-intensive firms**, who respond to tax incentives and there are **heterogeneities in responses** (Hall and van Reenen, 2000; Brown, Fazzari and Petersen, 2009; Boler et al, 2015; Dechezlepretre et al., 2016; Akcigit, Baslandze & Stantcheva, 2016; Guceri, 2017; Akcigit, Hanley & Stantcheva, 2017; Guceri and Liu, 2019; Chen, Liu, Suarez Serrato & Xu, 2021).

(3) **Asymmetric treatment of losses** within the tax system renders investment incentives less effective (Auerbach, 1986; Mayer, 1986; Devereux et al., 1994; Edgerton, 2010; Zwick and Mahon, 2017).

Asymmetric treatment of profits and losses in the corporate tax system may significantly **affect real decisions** of firms such as equilibrium level of investment, production, ...(Domar and Musgrave, 1944; Stiglitz, 1969; Auerbach, 1986):

1. Today, profit-making firms are taxed at 19-25% while **loss-makers do not get a refund**.
2. The system tries to alleviate this asymmetry by allowing **loss carry-backs** and **carry-forwards**.
3. The loss-making firm **takes into account the future value of loss offsets** when making investment decisions, calling for a dynamic investment model (Auerbach, 1986; Mayer, 1986).
4. The asymmetry is **likely to lessen the effect of tax incentives, but this is empirically difficult to pin down**, especially using accounting data (Devereux et al., 1994).
   Should incentives discriminate against companies with no taxable income?

... and 2 additional policy regimes for medium-sized companies, with the expansion of the more generous scheme to cover medium-sized companies:



Assumptions

Assumptions

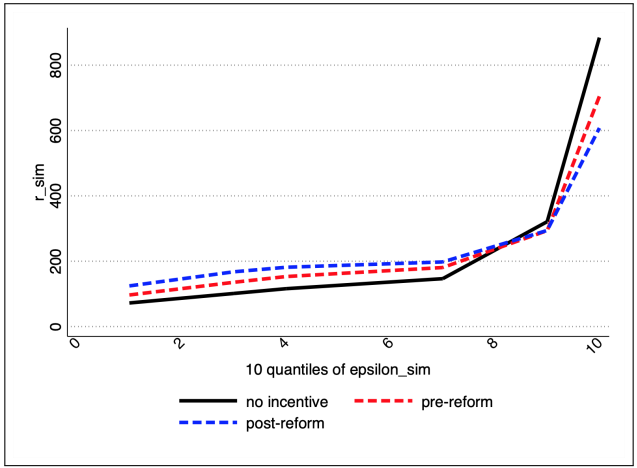
1. Timing: at time t, the firm decides on how much it will invest the next period, after the period t shock ε_t has been realised.
2. Competitive prices in outputs and inputs, prices are normalised to one.
3. The firm's only input is knowledge capital K_t, which is accumulated through R&D spending R_t.
4. Investment is irreversible.

GMM estimates of the production function

$$y_{it} = \rho y_{it-1} + \alpha_k k_{it} - \rho\alpha_k k_{it-1} + a_i(1-\rho) + \nu_{it}$$

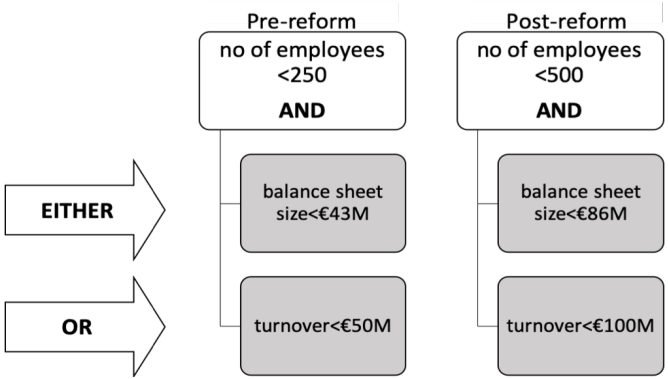
Dep.var: Log output	OLS	FE	DIF-GMM	SYS-GMM
y_{t-1}	0.972***	0.391***	0.256***	0.670***
	(0.002)	(0.015)	(0.027)	(0.023)
k_t	0.164***	0.154***	0.461***	0.694***
	(0.007)	(0.009)	(0.098)	(0.034)
k_{t-1}	-0.145***	-0.040***	-0.189***	-0.611***
	(0.007)	(0.008)	(0.059)	(0.032)
N	62,172	62,172	62,172	62,172

Simulation with $\lambda = 0.3$: how would R&D spending change in different regimes for firms with different productivity?

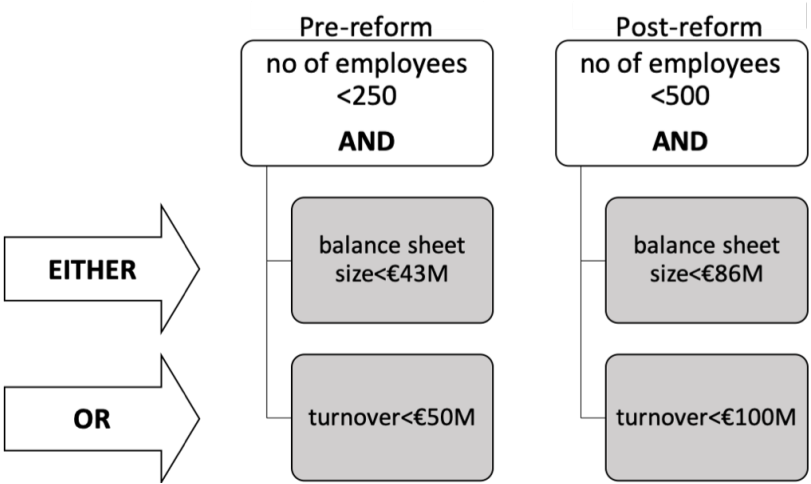


Reduced Form Estimates

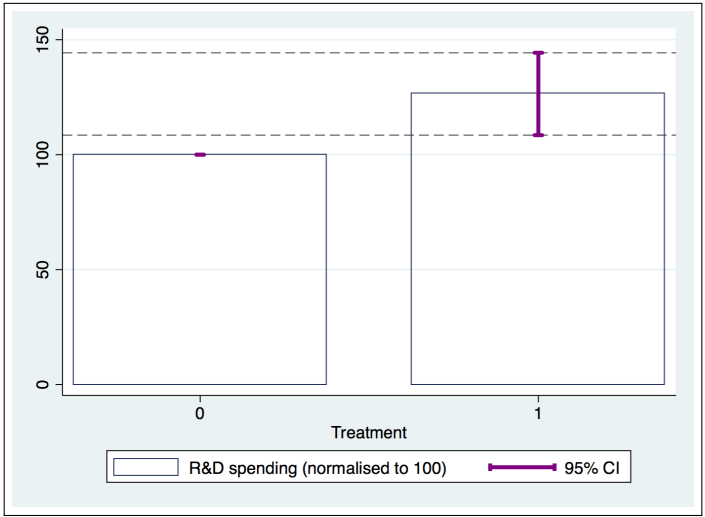
Recall the expansion in the cash scheme:



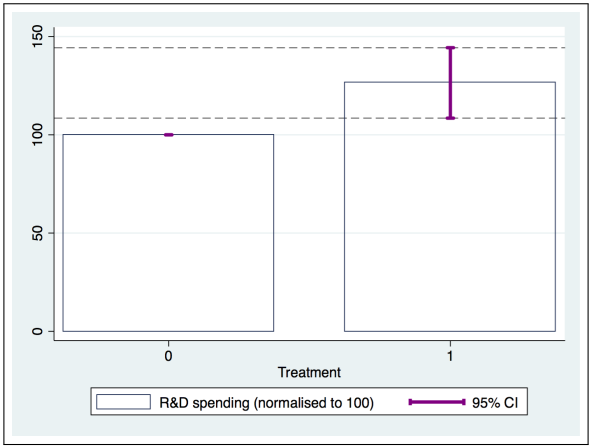
Reduced-form results on the effectiveness of tax breaks: set-up



Reduced-form result on the effectiveness of tax breaks: Guceri & Liu, 2019

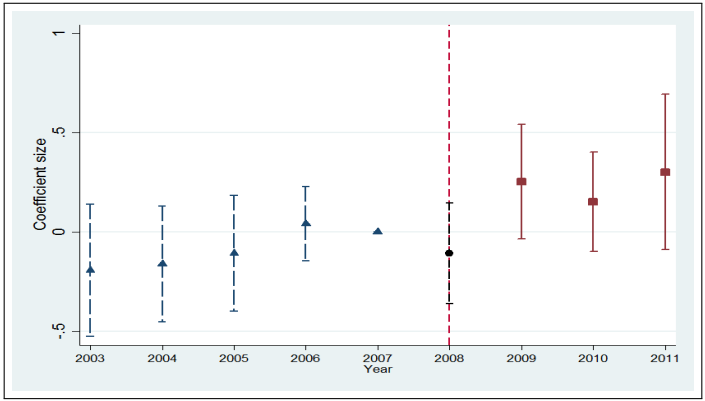


Earlier diff-in-diff results: tax incentives are useful for the average company



Source: Guceri and Liu, 2019

Diff-in-diff estimates tell us that treated firms differentially increase R&D spending in response to tax incentives



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This reform enables further exploration using diff-in-diff

1. Determine rules to allocate firms to 4 groups (next slide):
   (1) **financially constrained**, negative outlook
   (2) financially unconstrained, negative outlook
   (3) **financially constrained**, positive outlook
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5. Interact the ATET with a dummy on 'high likelihood of being constrained', H:

$$\mathbb{E}[R_{it}|D_{it}, \mathbf{X}_{it}] = \exp(a_i + \delta_l D_i T_t + \delta_l^H D_i T_t H_i + \delta_T^H T_t H_i + \mathbf{X}_{it}' \beta_x + \phi_t)$$

A taxonomy of cash refund responses, pre-reform - I

Pre-reform period		t+1	
		Trading Loss	Trading Profit
t	Cash	**Outlook:** Negative **Constraint:** Both types	**Outlook:** Positive **Constraint:** YES
	Carry Forward	**Outlook:** Negative **Constraint:** NO	**Outlook:** Positive **Constraint:** NO

A taxonomy of cash refund responses, pre-reform - II

Pre-reform period		**Frequency of Cash Taking** (cond. on having had the choice on 2+ occasions)	
		Always	Switching
t	Cash	**Outlook:** Negative **Constraint:** YES	**Outlook:** Negative **Constraint:** NO
	Carry Forward	**Outlook:** Negative **Constraint:** NO	**Outlook:** Negative **Constraint:** NO

Note: a check via Positive Outlook, Constrained types confirms the stability of constrained status.

Reduced-form results on young firms; dep.var: R&D spending

	1	2	3	4
Diff in diff, old	0.271	0.279	0.246	0.246
	(0.220)	(0.219)	(0.218)	(0.218)
Post 2008, old	0.321***			
	(0.078)			
Diff in diff * Young	0.725**	0.754**	0.789**	0.789**
	(0.339)	(0.326)	(0.327)	(0.327)
Post2008 * Young	-0.427**	-0.327*	-0.357*	-0.357*
	(0.200)	(0.197)	(0.199)	(0.199)
Revenues			0.000	0.000
($'000)			(0.000)	(0.000)
Revenue growth				0.000
				(0.000)
Year fixed effects?	No	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
N	8,926	8,926	8,926	8,926

Same remarks as in previous regression tables

Definition for "young": in 2007, bottom quartile in the age distribution

Characteristics that correlate with constrained status

Dep. var: 1(Constrained= 1)	LPM	Probit
Freq. Equity Issue	0.528***	1.459***
	(0.044)	(0.131)
Age	-0.006***	-0.015***
	(0.001)	(0.004)
Turnover	-0.009***	-0.028***
	(0.002)	(0.008)
Turn. Growth	0.015***	0.048***
	(0.005)	(0.017)
Group sub.	0.084***	0.248***
	(0.023)	(0.064)
Group parent	-0.102	-0.267
	(0.091)	(0.268)
R&D / Turnover	0.043***	0.241***
	(0.004)	(0.052)
Dropped var.s	*Foreign dum., Royalties dum.,*	
(used in H&W, 2007)	*Fixed asset ratio, Industry Debt/Assets*	
N	7986	7986

Results from diff-in-diff analysis

	(1)	(2)	(3)
Treated × Post Reform	0.271***	0.389***	-0.073
	(0.104)	(0.147)	(0.085)
Treated × Post Reform × Constrained		1.316*	1.626***
		(0.722)	(0.146)
Post Reform × Constrained		-1.597**	-1.603***
		(0.704)	(0.101)
Method	Poisson	Poisson	OLS
Dep.var: real R&D in	level	level	log
Firm fixed effects?	Yes	Yes	Yes
Year effects?	Yes	Yes	Yes
Turnover (lagged) control?	Yes	Yes	Yes
Turn. Growth (lagged) control?	Yes	Yes	Yes
N	10450	7675	4051