CEPR PUBLIC POLICY SYMPOSIUM 2011

Hosted by
University of St.Gallen

27-28 MAY 2011

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March 11, 2011

Abstract

Credit constraints are more frequent among growth companies with large investment opportunities. For the same reason, profit taxes may harm innovative firms more than standard ones. This paper develops a model of heterogeneous firms where an endogenous share opts for innovation and faces credit constraints in the subsequent expansion phase. We emphasize four results: (i) R&D subsidies not only encourage innovation but also relax financing constraints and help innovative firms to exploit investment opportunities to a larger extent. (ii) Taxes which are neutral according to the standard user cost theory of investment, still restrict expansion investment of constrained firms by reducing pledgeable cash-flow and thereby discourage innovation. (iii) A revenue neutral increase in profit taxes to finance larger R&D subsidies redistributes towards innovative firms and boosts aggregate productivity and welfare. (iv) A revenue neutral tax cut cum base broadening policy similarly boosts innovation and welfare.

JEL-Classification: G32, G38, H25.
Keywords: Profit taxes, R&D subsidies, innovation, investment, credit constraints.

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1 Introduction

Growth opportunities are distributed unevenly. Empirical evidence suggests a heterogeneity of firms along several dimensions and points to three important characteristics. First, small, closely held entrepreneurial companies are often very dynamic and more innovative than more mature firms. Their innovative nature creates large investment opportunities which makes them financially dependent. Second, the growth prospects of these firms depend on the technological know-how and managerial effort of a dominating entrepreneur. And third, young growth companies tend to have little own assets either because they are at an early stage of their life-cycle or because own resources have been drained at an early stage by substantial spending on R&D (research and development). The combination of these characteristics, i.e. large investment opportunities, little own resources and potential moral hazard with respect to entrepreneurial effort, makes it likely that these firms face credit constraints. Compared to innovative firms, other companies with less potential to invest and grow are also less likely to face restrictions in external financing.

A large empirical literature emphasizes the prevalence and importance of credit constraints. Rajan and Zingales (1998) document important sectoral differences in the external financial dependence of firms. Accordingly, financial development stimulates mostly the expansion of financially dependent relative to other sectors. In general, young and small firms are more likely to be credit constrained than large firms (cf. Schaller, 1993;

[0] We gratefully acknowledge financial support by the Swiss National Science Foundation (project no. 100014_129556/1). The paper was presented in research seminars at the Universities of St. Gallen and Innsbruck and at the annual meetings of the European Finance Association in Frankfurt, the European Financial Management Association in Aarhus, the European Economic Association in Glasgow, the German Economic Association in Kiel, the 66th Congress of the International Institute of Public Finance in Uppsala, the Annual Symposium of the Oxford University Centre for Business Taxation, the Journées d'Economie Publique Louis-André Gérard-Varet in Marseille, the Annual Congress of Swiss Society of Economics and Statistics in Fribourg, and at the CEPR workshop "Corporate Finance and Economic Performance" in St. Gallen, 2010. We appreciate helpful comments by seminar participants and the discussants Reto Foellmi, Matthew Rhodes-Kropf, Thomas Hemmelgarn and Marko Köthenbürger.

Jaramillo, Schiantarelli, and Weiss, 1996; Beck, Demirguc-Kunt, and Maksimovic, 2005; Aghion, Fally, and Scarpetta, 2007). Both entry and subsequent firm growth are limited by financial frictions (see Hubbard, 1998; Beck and Demirguc-Kunt, 2006; Aghion et al., 2007). Further, empirical research commonly finds that innovative firms face tighter financing restrictions than non-innovative firms (Himmelberg and Petersen, 1994; Guiso, 1998; Hyytinen and Toivanen, 2005; Ughetto, 2009; Hall and Lerner, 2010). Financial constraints are not only important at the firm level but are likely to restrain macroeconomic performance as well. Young and innovative firms have emerged as an important source of economic growth (Audretsch, 2002; Carree and Thurik, 2003). These firms are fast in adopting and developing new technologies or products, and consequently grow at a faster pace than larger established firms. Despite their small initial size, they contribute significantly to aggregate employment and productivity growth (cf. Roper, 1997; Audretsch, 2002). Kortum and Lerner (2000) attribute in 1998 roughly 14% of U.S. industrial innovation to young venture capital backed firms although they spend only about 3% of total R&D funds.

This paper explores how tax policy may influence innovation and aggregate investment when firms are heterogeneous and expansion investment of innovative companies is constrained by the availability of external funding. This endeavor is likely to be important since empirical research suggests that constrained and unconstrained firms respond in an entirely different way to profit taxation. According to traditional user cost theory, taxes affect investment of unconstrained firms exclusively by their impact on the user cost of capital (e.g. Hall and Jorgensen, 1967; Auerbach, 1983). Hassett and Hubbard (2002) review the empirical literature and report estimates of investment elasticities with respect to the user cost in the range between -0.5 and -1.0. In contrast, investment becomes sensitive to cash-flow, own collateral and institutional country characteristics when firms are finance constrained (see Hubbard, 1998, for a survey, and Bond and Söderbom, 2009, for a model based discussion of the empirical literature). Schaller (1993), Chirinko and Schaller (1995) and Hoshi, Kashyap and Scharfstein (1991) report elasticities of physical capital investment to cash-flow around 0.4-0.5. Estimates for total working capital are

significantly higher and vary between 0.8 to 1.3 (see Fazzari and Petersen, 1993; Calomiris and Hubbard, 1995; and Carpenter and Petersen, 2002). For these reasons, tax systems such as cash-flow taxes or an ACE system (allowance for corporate equity) which are neutral according to user cost theory, cannot be neutral if at least part of firms are finance constrained.[1] Although these tax systems have no impact on the user cost, they still retard investment of constrained firms by reducing pledgeable cash-flow. Given that finance constrained firms are often the most innovative ones, it seems important to explore how tax policy can endogenously affect not only investment scale but also the share of constrained firms and, thereby, aggregate innovation.

To investigate these issues, we propose a theoretical model where innovative firms face credit constraints. In a first stage, firms decide whether to make a discrete R&D investment or not. This decision margin endogenously explains the composition of the business sector between innovative and standard firms and, depending on the shares of these firms, aggregate productivity. The R&D investment has two consequences: it boosts productivity and, thereby, creates larger investment opportunities in the subsequent expansion stage. It also drains internal resources relative to standard firms which abstain from R&D. Both consequences make it likely that innovative growth companies face credit constraints in the subsequent expansion phase. Subsequent to the innovation decision, firms are heterogeneous with respect to investment opportunities. Standard firms need little external funding and are not credit constrained. They invest until the rate of return is equal to the user cost of capital. Innovative firms, in contrast, have a large need for external funding and are, by assumption, credit constrained. Their investment is determined by own resources which are leveraged with external funds up to a maximum limit which depends on pledgeable future cash-flow. Following Holmstrom and Tirole (1997) and Tirole (2006), a firm's pledgeable income reflects a moral hazard problem with respect to entrepreneurial effort. Entrepreneurs need to keep a minimum part of the company's

[1] These tax systems were shown to be neutral in the absence of financial frictions (see e.g. King, 1975; Sandmo, 1979; Boadway and Bruce, 1984). Bond and Devereux (1995, 2003) show that these alternatives are equivalent if tax rates are appropriately chosen.

earnings to assure their high effort, which limits the amount of income that can credibly be promised to banks and other external investors as a repayment. As a result, banks restrict credit, implying that a firm's investment at the margin is limited by its capacity to leverage own assets with external funds. Since investment is lower than the unrestricted level, innovative but finance constrained firms generate an excess return on investment.

Our model of constrained and unconstrained firms or, equivalently, of innovative and standard firms, allows us to study the effects of tax policy on innovation, capital investment and welfare. The analysis highlights transmission channels for tax policy that are entirely different across firms, depending on their financing capacity. We derive four novel results. First, R&D subsidies not only encourage innovation but also boost subsequent expansion investment. R&D subsidies are an important pillar of innovation policy in many countries, see OECD (2008), and Bloom, Griffith and Van Reenen (2002) for empirical evidence how a reduction in R&D costs stimulates R&D. In contrast to the existing literature which emphasizes innovation spillovers as a rationale for R&D subsidies (see Grossman and Helpman, 1991, for example), the welfare gains in our model derive from the fact that the subsidy also relaxes financing constraints and allows firms with an excess return to exploit investment opportunities to a larger extent. Second, taxes which are neutral according to standard user cost theory, still restrict expansion investment of constrained firms by reducing pledgeable cash-flow and thereby discourage innovation. Third, a revenue neutral increase in profit taxes to finance larger R&D subsidies redistributes towards innovative firms and boosts aggregate productivity and welfare. Fourth, even apparently non-discriminatory tax reforms can still redistribute across firms when they are in different financial regimes.[2] In this vein, we find that a revenue neutral tax cut cum base broadening policy favors the more profitable, innovative firms, relaxes their financing constraint, and consequently boosts innovation and welfare.

Existing literature in public economics has analyzed the implications of tax policy

[2] In a different context, Becker, Fuest and Riedel (2010) show that corporate taxes affect both the quality and quantity of FDI, leading to important compositional effects. They estimate that the quality effect accounts for around 40% of the total impact.

for entrepreneurship and entry in the presence of asymmetric information.[3] The present paper, in contrast, focusses on discrete innovation choice and subsequent expansion investment of firms. More recently, Chetty and Saez (2010) and Koethenbuerger and Stimmelmayr (2009) also consider the implications of agency costs on the scale of investment but take an alternative approach. These papers focus on the role of dividend and corporate taxes when managers make inefficient investment choices by diverting funds to 'pet' projects which do not generate income and yield utility (private benefits) only to managers but not to shareholders. Similarly, studying theft by company insiders, Desai, Dyck, and Zingales (2007) show that corporate taxes may lead to more theft and diversion of funds (see also the survey in Desai and Dharmapala, 2008, on the interaction of tax systems and corporate governance). In these papers, the agency problem is to prevent the misuse of company funds by corporate insiders. Gordon and Dietz (2008) compare the 'new view' of dividend behavior with a signaling model where managers pay dividends to signal to external investors that firms have more than enough cash on hand. We believe that these theories are more descriptive of the behavior of large unconstrained firms with diversified ownership and professional managers, creating a shareholder manager conflict over the firm's dividend policy and internal use of free cash-flow. Our approach, instead, focusses more on the role of finance constraints for investment of closely held entrepreneurial companies led by owner-managers that are unable to invest up to the efficient scale because they have difficulty in raising external funds.[4] To the best of our knowledge, our

[3]See Boadway and Keen (2006) for a synthesis and extension of the literature on the effects of taxes on adverse selection and entry, and Keuschnigg and Nielsen (2004a,b) on entrepreneurship with moral hazard. Unlike the present paper, this literature mostly assumes a fixed investment scale, making it difficult to compare to standard investment theory.

[4]Auerbach and Hasset (2002) emphasize that the marginal source of funds and associated dividend behavior varies across different types of firms. Chetty and Saez (2010) explain the extensive margin of dividend behavior, with a range of firms not paying any dividend at all. In our model, constrained firms do not pay dividends and use all available resources for internal financing of new investment. Unconstrained firms would have access to more external debt and could pay dividends. Our model, however, is not explaining and not focussing on the dividend decision.

paper is unique in explaining the coexistence and endogenous composition of constrained and unconstrained firms as a result of a discrete innovation decision.[5]

The paper proceeds as follows. Section 2 introduces the model. Section 3 derives comparative static results and prepares Section 4 which presents the main results on the impact of taxes and subsidies in a finance constrained economy. Section 5 concludes.

2 The Model

2.1 Overview

There is a mass 1 of risk-neutral agents with assets A per capita. A part $1-E$ invests in the deposit market to obtain end of period wealth AR where r is a safe rate of interest, and $R \equiv 1+r$. A fixed fraction E is also endowed with a two stage investment project and heterogeneous entrepreneurial ability. At an early stage, firms decide whether or not to undertake a fixed R&D investment with private cost $k_j \in \{0, (1-\sigma)\,k\}$ where σ is an R&D subsidy. At the subsequent stage, firms choose a variable scale of expansion investment I_j, conditional on the prior R&D decision. The firm can fail in each stage, and closes down in this event. Entrepreneurial ability is reflected in the early stage success probability $q' \in [0,1]$ of the project which is exogenously distributed by $G(q) = \int_0^q g(q')\,dq'$. In contrast, the success probability p of expansion stage investment is symmetric but may be high or low, depending on managerial effort. A high success probability is possible only with full effort while shirking (consumption of 'private benefits') results in a lower survival probability $p_L < p$. Conditional on R&D choice, firms in the expansion stage are either innovative or standard, but are otherwise symmetric within each group. Our

[5] We are not aware of any paper where both types of firms coexist within a unified framework. The agency problems in large firms, leading to misuse of free cash-flow, probably generate a social return on investment lower than the market rate of interest. We believe that this might even strengthen our results on redistribution and capital allocation across firms with different returns on investment. This might be an important topic for future research.

assumptions below imply that innovating firms will be finance constrained, indicated by an index $j = c$, while standard firms are unconstrained (index $j = u$).

Innovation has two consequences. First, R&D spending drains own resources and leaves low residual assets $A_c = A - (1 - \sigma) k$, whereas $A_u = A$. Second, innovation raises a firm's productivity from $\theta_u = 1$ to $\theta_c = \theta > 1$ and determines net output $x_j = \theta_j f(I_j)$ which is a strictly concave function of investment, $f' > 0 > f''$. Output x_j is zero if the firm fails either with probability $1-q'$ early on or with probability $1-p$ later. Due to their high productivity, innovating firms invest at a larger scale, leading to $I_c > I_u$, and are more profitable, leading to expected net of tax profits $\pi_c > \pi_u$. Given large investment opportunities and little own funds, innovating firms require a much larger credit and are naturally dependent on external financing. The timing of events is: (i) Conditional on project type q', the firm decides on R&D; (ii) If the early stage is successfully completed, the firm chooses expansion investment I_j and raises the required credit $D_j = I_j - A_j$; (iii) The entrepreneur chooses managerial effort, leading to p when effort is high, or p_L when private benefits are enjoyed; (vi) The firm produces output and pays back credit if investment is successful. The model is solved by backward induction.

Anticipating subsequent decisions, expected net profit ex ante is

$$\pi_E = \int_0^q \pi_u q' dG(q') + \int_q^1 [\pi_c q' - Rk_c] \, dG(q'). \tag{1}$$

Our assumptions imply that only good projects $q' > q$ warrant R&D to obtain a higher productivity and larger net present value $\pi_c q' - Rk_c$. Other firms with low quality projects $q' < q$ do not innovate, avoid R&D spending, and get only a smaller expected value $\pi_u q'$. Expected profit is positive as will be shown in equation (9) below.

2.2 Investment and Innovation

When the firm arrives at the expansion stage, it chooses a variable investment scale and raises external funds, $D_j = I_j - A_j$. Since own resources are predetermined, the marginal

source of finance is debt.[6] The loan rate for risky business debt is $i > r$. The government taxes profit at the rate τ but allows deduction of a share λ of total financing costs iI_j. The tax liability is $T_j = \tau (x_j - \lambda i I_j)$ if the firm survives the expansion stage. Net of the R&D subsidy, the total end of period value of an innovating firm's tax liability amounts to $T_c - \sigma kR$ if it is successful in all stages. Setting $\lambda = 1$ and $\sigma = \tau$, the tax is equivalent to an ACE (allowance for corporate equity) system.[7] The expected profit (or surplus over own assets A_j) of an entrepreneur with a type j firm is

$$\begin{aligned} \pi_j^e &= p \left[I_j + x_j - (1+i) D_j - T_j \right] - RA_j, \\ \pi_j^b &= p (1+i) D_j - RD_j = 0, \\ \pi_j &= p (I_j + x_j - T_j) - RI_j. \end{aligned} \tag{2}$$

We assume a perfectly competitive capital market. Hence, in equilibrium, the competitive loan rate is determined by the zero profit condition $p(1+i) = R$. Expected repayment matches the bank's refinancing cost on the deposit market. To cover the losses from credit default, the loan rate must exceed the safe deposit rate. Given that banks make zero profits, the entrepreneur appropriates the entire joint surplus of the firm, $\pi_j^e = \pi_j$. Define the user cost of capital u and write expected net of tax profit of a type j firm as

$$\pi_j = (1-\tau) p (x_j - uI_j), \quad u \equiv \frac{1-\lambda\tau}{1-\tau} \cdot i. \tag{3}$$

When $\lambda = 1$, the tax has no impact on the user cost, i.e., $u = i$.

Given innovation and investment choices at earlier stages, and a level of debt, the entrepreneur obtains a surplus $v_j^e \equiv I_j + x_j - (1+i) D_j - T_j$ if the firm survives. If she

[6] We phrase external funding in terms of debt. In this simple two state model, new debt and new equity are, in fact, equivalent in the absence of tax so that D_j could also be interpreted as new equity. However, if there is a tax advantage of debt, agents would strictly prefer debt over equity.

[7] See Boadway and Bruce (1984), and Bond and Devereux (1995, 2003) on the equivalence between ACE and cash-flow taxes. In reality, usually only interest on debt is deductible while the opportunity cost iA_j of equity is not. The tax liability would be $\tau (x_j - iD_j)$. We choose the current formulation partly for simplicity but also to emphasize that even a 'neutral' tax that doesn't change the user cost, discourages investment of constrained firms.

works hard, the success probability and expected income pv_j^e will be high. Alternatively, shirking results in a low survival probability and a low expected income $p_L v_j^e$, but the entrepreneur can enjoy private benefits bI_j. The incentive condition for high effort is

$$pv_j^e \geq p_L v_j^e + bI_j \quad \Leftrightarrow \quad v_j^e \geq \beta I_j, \quad \beta \equiv b/\left(p - p_L\right). \tag{4}$$

Incentive compatibility is assured only if the entrepreneur keeps a minimum stake $v_j^e \geq \beta I_j$ so that the increase in expected income as a result of high effort exceeds foregone private benefits from shirking. Since we want to focus on equilibria where innovative firms are credit constrained and standard firms are not, we impose the following assumption:

Assumption 1 *(i) At I_u given by $f'\left(I_u\right) = u$, the constraint is slack, $v_u^e\left(I_u\right) > \beta I_u$. (ii) At I_c given by $\theta f'\left(I_c\right) = u$, the incentive constraint is violated, $v_c^e\left(I_c\right) < \beta I_c$.*

Assumption (i) implies that standard firms are unconstrained. In maximizing expected end of period wealth $\pi_u^e = pv_u^e - RA$, standard firms expand until the return on investment is equal to the user cost of capital,

$$f'\left(I_u\right) = u. \tag{5}$$

Innovative firms have less internal funds, $A_c = A - (1-\sigma)\,k$, but have higher productivity and more profitable investment opportunities than standard firms. Part (ii) of the above assumption means that they are unable to fully exploit their growth potential. Investment is restricted by the binding incentive constraint $v_c^e \geqslant \beta I_c$. Multiply by p, substitute v_c^e and $D_c = I_c - A_c$, and use π_c as well as $(1+i)\,p = R$ to get the constraint

$$\pi_c = (1-\tau)\,p\left[\theta f\left(I_c\right) - uI_c\right] \geqslant p\beta I_c - RA_c. \tag{6}$$

Figure 1 illustrates how the incentive constraint implicitly determines investment of a credit rationed firm. Unconstrained values are marked by a star.

At any investment level, expected profit of innovative firms is larger since they are more productive as a result of prior R&D ($\theta > 1$). Standard firms invest until expected profit

is at a maximum. They have undiminished wealth A so that the line $p\beta I_u - AR$ starts out at $-AR$. Clearly, at the optimal investment level I_u^*, the incentive constraint is slack, $\pi_u\left(I_u^*\right) > p\beta I_u^* - AR$. If innovative firms had no financing problem, they would invest I_c^* to maximize expected profit. However, when banks anticipate that a debt obligation of this size violates the entrepreneur's incentive constraint so that the loan would be repaid only with a lower probability $p_L < p$, they deny the required funding since they could not break even with the competitive loan rate i. The firm is able to raise credit only up to $I_c - A_c$ and can invest no more than $I_c < I_c^*$ when the incentive constraint becomes binding as in Figure 1.[8]

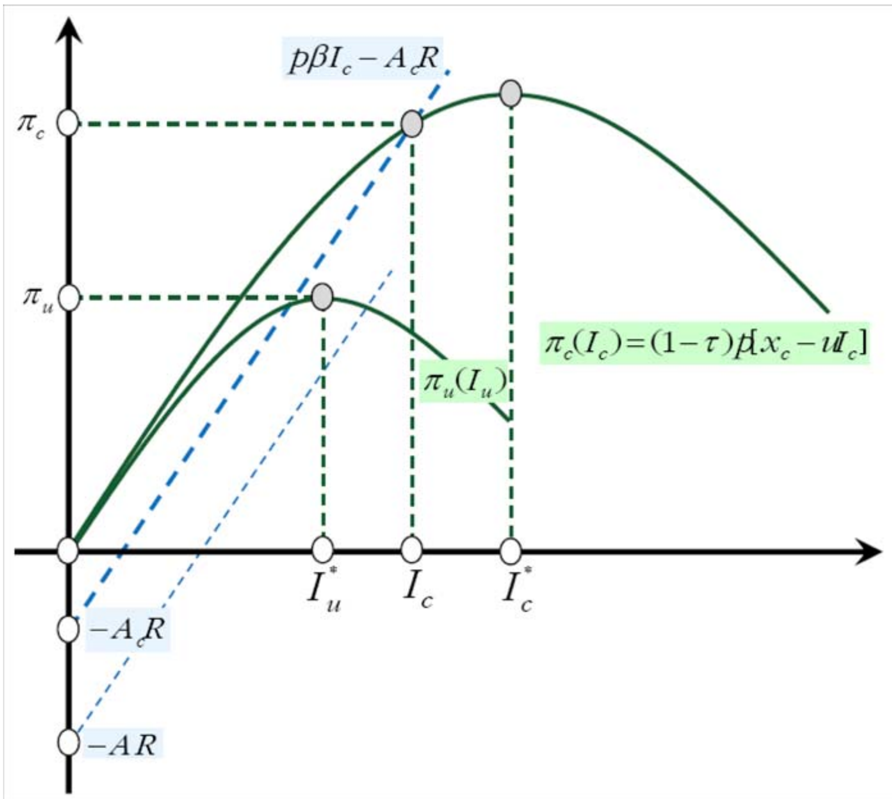

Fig. 1: Incentive Compatible Investment

[8]If the firm asked for a marginally larger credit, banks could still provide credit by discretely raising the loan rate to $i_L > i$ until $(1+i_L)\,p_L = R$. Profit v_c^e would marginally rise if i were not changed but falls discretely if the loan rate rises to i_L. At this higher rate, the bank would break even at any credit size. We must assume p_L low enough so that firms do not prefer the contract with low effort, i.e. $\pi_c = (1-\tau)\,p\,[\theta f\,(I_c) - uI_c] > \pi_L = (1-\tau)\,p_L\,[\theta f\,(I_L) - u_L I_L]$, where I_L is the unconstrained investment scale at user cost u_L. An equilibrium with shirking is definitely not viable if $p_L \to 0$.

The choice of expansion investment results in profits that firms can expect conditional on the level of R&D. As Figure 1 illustrates, R&D leads to higher profits but comes at an additional fixed cost. Firms must decide on their innovation strategy before the development risk is resolved. They differ by the quality of their business idea which is reflected in a given probability q' of successfully completing the start-up phase. With probability $1 - q'$, the firm fails and closes down. Any R&D investment is lost. Firms of type q' invest in R&D if $q'\pi_c - (1 - \sigma)\, kR \geq q'\pi_u$, giving the cut-off value

$$q = \frac{(1 - \sigma)\, kR}{\pi_c - \pi_u} < 1. \tag{7}$$

Firms with higher potential $q' > q$ invest in R&D, less promising ventures do not. Figure 2 illustrates.

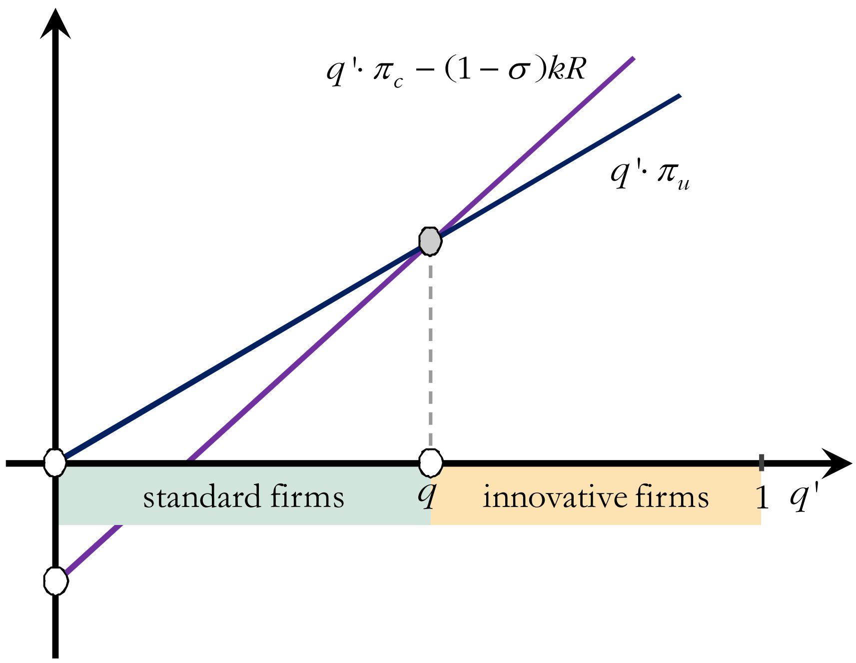

Fig. 2: Innovation Decision

In the beginning, when firms have not yet learned the nature of their project but know only the distribution of possible types, expected profit is given by (1). By the law of large numbers, the ex ante innovation probability s_k is equal to the share of innovating firms ex post. A share $1 - s_k$ of firms perform no R&D. Only a part $s_c < s_k$ of firms successfully

innovate, and a part $s_u < 1 - s_k$ are successful without innovation:

$$s_u = \int_0^q q' dG(q'), \quad s_c = \int_q^1 q' dG(q'), \quad s_k = \int_q^1 dG(q'). \tag{8}$$

Anticipating subsequent innovation and investment decisions thus yields

$$\pi_E = s_u \pi_u + s_c \pi_c - s_k (1-\sigma) kR > 0. \tag{9}$$

Expected profit $\pi_E = \int_0^1 \pi_u q' dG(q') + \int_q^1 [(\pi_c - \pi_u) q' - (1-\sigma) kR] dG(q')$ is positive since the square bracket is zero at the cut-off but strictly positive for better types. All potential entrepreneurs strictly prefer entry and invest their wealth A in their own firm rather than in the capital market. Out of E firms, only a part $s_k E$ invest in R&D and only $s_j E$ survive the early stage. Out of these, a fraction $1-p$ fails in the expansion stage, and only a part $ps_j E$ makes it to the production stage.[9]

2.3 General Equilibrium

The government collects taxes from firms and could use them to pay for public goods or redistributive transfers. Since the aim of this study is to isolate the efficiency implications of profit taxation in the presence of financing constraints, we assume that tax revenues are refunded back to firms. At the same time, we assume that these transfers are received in the private sphere and cannot be pledged to banks to raise larger credit. This assumption is meant to reflect the fact that, in reality, firms do not receive lump-sum transfers from the government but only for specific purposes such as R&D subsidies or infrastructure. Hence, the entrepreneur's expected end of period utility is $v_E = AR + \pi_E + T_E$. Aggregate tax revenue amounts to $T_E E$, or T_E per firm,

$$T_E = \sum_j ps_j T_j - \sigma s_k kR, \quad T_j = \tau (x_j - \lambda i I_j). \tag{10}$$

Appendix A states the equilibrium conditions on deposit and output markets. Given a fixed deposit rate, these conditions are not relevant for further analysis.

[9] Suitable restrictions on parameters k, A, θ, and β will ensure that an interior equilibrium exists and satisfies four conditions: (i) standard firms are not constrained; (ii) innovative firms are credit rationed; (iii) innovative firms invest at a larger scale, $I_c > I_u$; and (iv) only a share of firms chooses R&D.

3 Comparative Static Analysis

The policy scenarios in the next section are concerned with changes in tax parameters τ, λ and σ. To prepare, the comparative static analysis of this section shows how investments, profits and innovation respond to policy shocks. The hat notation denotes a percentage change of a variable relative to its value in initial equilibrium, e.g., $\hat{I}_j \equiv dI_j/I_j$. Exceptions such as the change in tax rates $\hat{\tau} \equiv d\tau/(1-\tau)$ and $\hat{\sigma} \equiv d\sigma/(1-\sigma)$, are especially indicated. We assume that an ACE tax is in place in the initial equilibrium, $\lambda = 1$ and $\sigma = \tau$, implying a user cost $u = i$. This assumption not only simplifies calculations but also helps to focus on the non-standard effects of tax policy where taxes do not work via the user cost channel but via the cash-flow sensitivity of constrained investment.

3.1 Investment and Profits

The exogenous deposit rate fixes the loan rate i via the zero profit condition $(1+i)\,p = R$. Investment of standard firms is determined by (5) and changes by

$$\hat{I}_u = u_\lambda \cdot \hat{\lambda}, \quad u_\lambda \equiv \frac{\tau}{1-\tau}\frac{1}{1-\alpha}, \quad -\frac{f'(I_j)}{I_j f''(I_j)} = \frac{1}{1-\alpha} > 1. \tag{11}$$

In starting from $\lambda = 1$ and $u = i$, a larger tax rate does not affect the user cost and has no impact on investment. By the envelope theorem, profit of a standard firm changes by

$$d\pi_u = -\pi_u \cdot \hat{\tau} + \tau p i I_u \cdot \hat{\lambda}. \tag{12}$$

Base broadening ($\hat{\lambda} < 0$) discourages investment while a change in the tax rate has no effect since the tax is neutral in the initial equilibrium. Raising the tax rate and broadening the tax base both shrink expected net of tax profit of the firm.

When firms are constrained, investment is implicitly determined by the binding incentive constraint in (6). In taking the differential, we define the excess return $\rho \equiv (1-\tau)(x_c' - i)$ on constrained investment, evaluate at $\lambda = 1$, and use A_c and u, to show how investment responds to taxes,

$$\hat{I}_c = -\frac{\pi_c}{mI_c} \cdot \hat{\tau} + \frac{\tau i p I_c}{mI_c} \cdot \hat{\lambda} + \frac{(1-\sigma)\,kR}{mI_c} \cdot \hat{\sigma}, \quad m \equiv (\beta - \rho)\,p < R. \tag{13}$$

The assumption $m < R$ guarantees positive leverage of own assets, $dI_c/dA > 1$.

If a firm is unconstrained, investment is exclusively driven by the user cost of capital as in (11). In contrast, taxes affect investment of a constrained firm via their impact on pledgeable income. To compare to the unconstrained case, we rewrite (13) as

$$\hat{I}_c = -\phi_\tau \cdot \hat{\tau} + (u_\lambda + \phi_\lambda) \cdot \hat{\lambda} + \phi_\sigma \cdot \hat{\sigma}, \tag{14}$$

where the ϕ-coefficients are defined as

$$\phi_\tau \equiv \frac{\pi_c}{mI_c}, \quad \phi_\lambda \equiv \frac{\tau ip}{m} - u_\lambda \gtrless 0, \quad \phi_\sigma \equiv \frac{(1-\sigma)\,kR}{mI_c}.$$

Setting the ϕ-parameters to zero recovers the unconstrained case where $\hat{I}_c = u_\lambda \hat{\lambda}$. Neither the tax nor the subsidy rate, τ and σ, affect expansion investment because they do not enter the user cost of capital. When firms are finance constrained, investment becomes sensitive to cash-flow. The tax rate reduces future cash-flow and thereby erodes the firm's pledgeable income while the subsidy strengthens residual own equity A_c after R&D spending. Both a tax cut and a higher subsidy boost the firm's financing capacity and thereby facilitate investment. Base broadening by limiting the deduction rate λ for financing costs also inflates the tax liability, reduces pledgeable cash-flow and thereby restricts investment.[10]

Starting with $\lambda = 1$, the expected profit in (3) changes by

$$d\pi_c = -\pi_c \cdot \hat{\tau} + \tau ipI_c \cdot \hat{\lambda} + \rho pI_c \cdot \hat{I}_c. \tag{15}$$

The first two terms are structurally identical to (12). However, when investment is constrained, the envelope theorem no longer applies so that larger investment boosts profits. The impact on profit is proportional to the excess return $\rho > 0$. We summarize:

Proposition 1 (Excess Return) *Financially constrained firms earn a return on investment in excess of the user cost of capital, $\rho \equiv (1-\tau)(x_c' - i)$. More investment would raise the joint surplus π_c in the expansion stage.*

[10] The effect now operates via the cash-flow and not via the user cost channel. Note that there is no clear-cut argument to sign ϕ_λ, meaning that the effect of λ may be stronger or weaker than in the unconstrained case. However, the net effect is clearly positive, as (14) shows.

3.2 Innovation, Productivity and Firm Value

Prior to expansion investment, firms decide on the (discrete) innovation strategy. R&D raises future productivity but also drains the firm's financial resources. The return to innovation consists of the anticipated increase in future profit, but accrues only if a firm actually survives. When it fails, the R&D investment is lost. In consequence, innovation is profitable only for the firms with the best prospects. The cut-off value q changes by $\hat{q} = -\frac{d\pi_c - d\pi_u}{\pi_c - \pi_u} - \hat{\sigma}$. Inserting profit changes from (12) and (15) and substituting the investment response of constrained firms from (14) yields

$$\hat{q} = \zeta_\tau \cdot \hat{\tau} - \zeta_\lambda \cdot \hat{\lambda} - \zeta_\sigma \cdot \hat{\sigma}, \tag{16}$$

where elasticities are defined to be positive,

$$\zeta_\tau \equiv 1 + \frac{\rho p I_c \phi_\tau}{\pi_c - \pi_u}, \quad \zeta_\lambda \equiv \frac{\tau p i \left(I_c - I_u\right) + \rho p I_c \left(u_\lambda + \phi_\lambda\right)}{\pi_c - \pi_u}, \quad \zeta_\sigma \equiv 1 + \frac{\rho p I_c \phi_\sigma}{\pi_c - \pi_u}.$$

Obviously, R&D tax credits (or subsidies) boost innovation. Since innovative firms are more productive, earn larger profits and invest at a larger scale, a higher tax rate reduces the share of innovating firms by raising the innovation threshold. Restricting tax deductions ($\hat{\lambda} < 0$) triggers the same impact. The innovation response would be qualitatively the same even if innovative firms were not constrained (set $\rho = 0$ in the elasticities). Financing constraints merely magnify the response.

Innovation boosts productivity. There are $s_c pE$ highly productive, innovative firms in the total pool $(s_c + s_u)\, pE$, resulting in average productivity $\theta_E = (\theta s_c + s_u) / (s_c + s_u)$ where the denominator is a constant. The composition of firms changes by $ds_c = q ds_k = -ds_u = -q^2 g\,(q)\,\hat{q}$, see (8). If more firms innovate ($\hat{q} < 0$), average productivity rises by

$$d\theta_E = -\left(\theta - 1\right) \frac{q^2 g(q)}{s_c + s_u} \cdot \hat{q}. \tag{17}$$

Welfare of investors and entrepreneurs is equal to end of period wealth, $v_N = AR$ and $v_E = AR + \pi_E + T_E$, respectively, which yields a utilitarian welfare measure $V = v_E E + v_N \left(1 - E\right)$. Incentive compatibility prevents entrepreneurs to consume private

benefits. Since investors are not affected, welfare changes in proportion to dv_E. One must know the impact on the net value π_E and the total net tax liability T_E per firm. Taking the differential of (9), expected profit changes by $d\pi_E = \sum_j s_j d\pi_j + (1-\sigma)\, s_k kR\hat{\sigma}$ where the compositional effects from $ds_c = qds_k = -ds_u$ cancel out. A rising cut-off q implies fewer innovating firms and lower productivity. However, on account of the innovation choice in (7), a marginal change in firm composition does not affect expected total profit of a new firm. Substituting (12), (14) and (15) and defining $\bar{\pi} \equiv s_c\pi_c + s_u\pi_u$ as well as $\bar{I} \equiv s_c I_c + s_u I_u$ yields

$$\begin{aligned} d\pi_E &= -\left(\bar{\pi} + \rho p s_c I_c \phi_\tau\right) \cdot \hat{\tau} + \tau p i \left(\bar{I} + \rho p s_c I_c / m\right) \cdot \hat{\lambda} \\ &: \quad + \left((1-\sigma)\, s_k kR + \rho p s_c I_c \phi_\sigma\right) \cdot \hat{\sigma}. \end{aligned} \tag{18}$$

The profit elasticities are magnified by the excess return ρ of constrained firms.

The expected *net* tax liability is $T_E = \sum_j s_j pT_j - \sigma kRs_k$. Evaluating at $\lambda = 1$, the expected tax pT_j changes by

$$pdT_j = \pi_j \cdot \hat{\tau} - \tau p i I_j \cdot \hat{\lambda} + \frac{\tau}{1-\tau} p\rho_j I_j \cdot \hat{I}_j. \tag{19}$$

Using $ds_u = q^2 g(q)\hat{q} = -ds_c = -qds_k$, total net tax T_E changes by

$$dT_E = \sum_j s_j \cdot pdT_j - (1-\sigma)\, kRs_k \cdot \hat{\sigma} - \nabla_T q g(q) \cdot \hat{q}, \quad \nabla_T \equiv p\left(T_c - T_u\right) q - \sigma kR,$$

where ∇_T is the change in total tax liability when a marginal firm switches the innovation status. Substituting (19) and noting $\rho_u = 0$ yields

$$dT_E = \bar{\pi} \cdot \hat{\tau} - \tau p i \bar{I} \cdot \hat{\lambda} - (1-\sigma)\, kRs_k \cdot \hat{\sigma} + \frac{\tau}{1-\tau} p\rho s_c I_c \cdot \hat{I}_c - \nabla_T q g(q) \cdot \hat{q}. \tag{20}$$

The first three terms are the direct, mechanical effects of policy on expected tax revenue per firm. The last two terms reflect behavioral responses which will be substituted later, depending on the specific scenario.

Finally, subsequent analysis will require to sign the term ∇_T when an ACE tax is in place ($\lambda = 1$ and $\sigma = \tau$). In this case, gross profits $\pi_j^* = p\left(x_j - iI_j\right)$ are related to net of

tax profits by $\pi_j = (1-\tau)\,\pi_j^*$. Expected tax liability is $pT_j = \tau\pi_j^*$. The innovation cut-off becomes $(1-\tau)\,(\pi_c^* - \pi_u^*)\,q = (1-\tau)\,kR$. Hence, in an equilibrium with an arbitrary tax rate and an ACE system, the term $(\pi_c^* - \pi_u^*)\,q$ is fixed at kR, leaving

$$\nabla_T = p\,(T_c - T_u)\,q - \tau kR = \tau\,(\pi_c^* - \pi_u^*)\,q - \tau kR = 0. \tag{21}$$

In an equilibrium with $\lambda = 1$ and $\sigma = \tau$, the change in expected tax liability when a marginal firm switches the innovation decision, is zero.

4 Tax Policy and Financial Dependence

4.1 Introducing an R&D Tax Credit

We first consider the implications of an R&D tax credit, i.e. a subsidy to private R&D spending. To isolate the efficiency effects, we assume that the subsidy is financed by a lump-sum tax T_E (negative transfer) at the end of the period. To be lump-sum, it must not affect lending decisions of banks and effort choice of entrepreneurs. We thus assume that this tax is paid in the 'private sphere' and does not affect pledgeable income of the firm.[11] In any case, the scenario is meant to isolate the efficiency effects of the subsidy and to clarify the consequences when firms are finance constrained. We also assume $\tau = 0$ in this subsection and turn to self-financed R&D subsidies in the following subsections.

The R&D subsidy is irrelevant for standard firms which do not spend on R&D. Both investment and profits at the expansion stage remain constant, $\hat{I}_u = d\pi_u = 0$. However, the subsidy has interesting and non-trivial implications for the expansion stage of innovative firms. The key insight is that R&D spending at an early stage drains internal resources that are needed to self-finance part of subsequent expansion investment. The

[11] Alternatively, the tax could be imposed on investors who cannot avoid it. It would reduce their welfare to $v_N = AR - T_N$, with fiscal balance requiring $ET_E + (1-E)\,T_N = 0$. To isolate efficiency gains, one would consider the change in aggregate welfare $V = Ev_E + (1-E)\,v_N$.

subsidy thus relaxes the financing constraint. By (14-16),

$$\hat{I}_c = \phi_\sigma \cdot \hat{\sigma} > 0, \quad d\pi_c = \rho p I_c \phi_\sigma \cdot \hat{\sigma} > 0, \quad \hat{q} = -\zeta_\sigma \cdot \hat{\sigma} < 0. \tag{22}$$

By strengthening internal funds, the subsidy allows for more self-financing and additional external leverage of expansion investment. In other words, the R&D subsidy not only encourages R&D activity but also helps firms to exploit new investment opportunities to a larger extent. This novel role of R&D tax credits also boosts profits in the expansion stage in proportion to the excess return ρ on constrained investment. The profit gain would not be present if firms were unconstrained. In that situation, investment would be expanded until the marginal return equals the user cost of capital so that the excess return would be zero. Another consequence of the R&D subsidy is that a larger profit of an innovative firm in the expansion stage reinforces the firm's incentives to engage in R&D. This extra profit gain reduces the innovation threshold q beyond the direct effect of an R&D subsidy. Noting the elasticity $\zeta_\sigma = 1 + \rho p I_c \phi_\sigma / (\pi_c - \pi_u)$, the direct effect $\hat{q} = -\hat{\sigma}$ is magnified by the increased profitability of innovation when the firm is able to exploit subsequent growth opportunities to a larger extent.

An R&D subsidy yields a first order welfare gain even if the subsidy is small. The welfare gain arises not because of knowledge spillovers as is traditionally argued. The present model excludes external effects of R&D. The gains arise because the subsidy relaxes the financing constraint and thereby allows innovative firms to invest more at an above average, excess return which raises aggregate income. To verify this, read the changes in expected profit and required tax revenue to pay for the subsidy from (18) and (20). Note that the differential budget cost of one more firm choosing to innovate is $\nabla_T = -\sigma k R$ as long as the profit tax rate is zero. Hence, using (22),

$$\begin{aligned} d\pi_E &= [(1-\sigma) k R s_k + \rho p s_c I_c \phi_\sigma] \cdot \hat{\sigma}, \\ dT_E &= -[(1-\sigma) k R s_k + \sigma k R q g(q) \zeta_\sigma] \cdot \hat{\sigma}. \end{aligned} \tag{23}$$

The subsidy boosts profits not only directly by subsidizing private R&D costs but also indirectly, in proportion to the excess return ρ, by stimulating expansion investment. The

direct tax cost of subsidizing R&D of all innovating firms is $dT_E = -(1-\sigma)\,kRs_k\hat{\sigma}$. Since the subsidy reduces the innovation threshold q, the government must subsidize even *more new* innovators at an extra budget cost of $dT_E = \sigma kR \cdot qg(q)\,\hat{q} < 0$.

Since investors are not affected in our scenarios, welfare changes in line with $v_E = AR + \pi_E + T_E$, see the discussion following (17). Adding up the two components in (23) shows that net welfare rises by

$$dv_E = d\pi_E + dT_E = [\rho p s_c I_c \phi_\sigma - \sigma kR \cdot \zeta_\sigma \cdot qg(q)] \cdot \hat{\sigma}. \tag{24}$$

In the present model, knowledge spillovers and other external effects of innovation are exluded by assumption. When finance constraints are not binding ($\rho = \phi_\sigma = 0$ and $\zeta_\sigma = 1$), excess returns are fully eliminated in equilibrium. Innovation would be Pareto optimal. Consequently, the optimal subsidy would be zero. Any positive value would only introduce an excess burden so that welfare would decline in proportion to the subsidy rate, $dv_E = -\sigma kR\zeta_\sigma qg(q)\,\hat{\sigma}$. In contrast, if innovative growth companies, characterized by little own funds and large investment opportunities, are finance constrained, a subsidy payment of value σkR boosts pledgeable income and allows firms to expand investment, not only because of larger own resources but also because of more external funds. In better exploiting investment opportunities from innovation, these firms generate additional net income to society where the income gains are proportional to the excess return $\rho = x_c' - i$. Clearly, it is welfare improving to introduce a small subsidy starting from $\sigma = 0$, $dv_E = \rho p s_c I_c \phi_\sigma \hat{\sigma} > 0$. As the rate becomes positive and more firms innovate to capture the subsidy, the standard excess burden kicks in. Further raising the subsidy becomes ever more costly. In the absence of other policies, the subsidy would be optimal when the marginal gains from relaxing finance constraints are balanced by the excess burden, i.e., $\rho p s_c I_c \phi_\sigma = \sigma kR \cdot \zeta_\sigma \cdot qg(q)$ holds. To sum up, we state:

Proposition 2 (R&D Subsidy) *An R&D subsidy (i) boosts innovation and augments the share of constrained firms; (ii) stimulates investment and profit of constrained firms; and (iii) a small subsidy yields first order welfare gains.*

4.2 Profit Taxation

To highlight the impact of tax reform on innovation and, thus, on capital investment of more or less profitable firms, we first consider a profit tax that does not affect the user cost of capital (an ACE tax, $\lambda = 1$ and $\sigma = \tau$). In allowing a full tax deduction of innovation costs, the tax would be fully neutral in an unconstrained equilibrium, not only with respect to equipment investment but also with respect to the innovation choice. Thus, our scenario yields a clear benchmark to isolate the implications of financing constraints. Since we want to focus on efficiency effects, we follow the approach in the preceding subsection and refund revenues as lump-sum transfers T_E to entrepreneurs.

Raising the tax rate $\hat{\tau} = \hat{\sigma}$ and keeping $\lambda = 1$ does not impair investment of standard, unconstrained firms, $\hat{I}_u = 0$, since this tax has not impact on the user cost of capital. However, being a tax on rent, it squeezes net of tax profits by $d\pi_u = -\pi_u \hat{\tau}$. In contrast, the tax not only reduces profits of innovative firms but also investment which is sensitive to cash-flow. Restricting investment further erodes profits in proportion to the excess return ρ, see (15). For this reason, the tax discriminates against innovative and more profitable firms. Innovation is discouraged and the share of constrained firms falls. Evaluating (16), we compute $\hat{q} = (\zeta_\tau - \zeta_\sigma)\,\hat{\tau}$ which gives

$$\hat{I}_c = -\left(\phi_\tau - \phi_\sigma\right) \cdot \hat{\tau} < 0, \quad \hat{q} = \rho p I_c \frac{\phi_\tau - \phi_\sigma}{\pi_c - \pi_u} \cdot \hat{\tau} > 0. \tag{25}$$

Given the condition for discrete innovation choice in (7) together with $\sigma = \tau$, we clearly find a positive sign of $\phi_\tau - \phi_\sigma = \left[(1-q)\,\pi_c + q\pi_u\right] / \left(m I_c\right) > 0$. Hence, the tax further constrains investment of innovative firms and discourages innovation.

To obtain welfare results, one must derive the change in expected tax revenue and profit. Note $\nabla_T = 0$ as in (21), substitute the investment response above and use $\pi_E = \bar{\pi} - (1-\sigma)\,kRs_k > 0$,

$$dT_E = \left[\pi_E - \frac{\tau}{1-\tau} \rho p s_c I_c \left(\phi_\tau - \phi_\sigma\right)\right] \cdot \hat{\tau}. \tag{26}$$

The last term reflects the loss in revenue when the tax further restricts investment and additionally reduces profit of constrained firms in proportion to the excess return. This

behavioral effect would be zero in the absence of financing constraints (ϕ-coefficients and ρ would be zero). At least for rates not too large, the tax raises revenue by taxing rents.

Finally, we evaluate the change in expected profits in (18)

$$d\pi_E = -\left[\pi_E + \rho p s_c I_c \left(\phi_\tau - \phi_\sigma\right)\right] \cdot \hat{\tau} < 0. \tag{27}$$

By the arguments above, the expression in the square bracket is clearly positive. The ACE system taxes rent and squeezes profits. Different from the standard case, it also constrains investment and thereby destroys unexploited profit opportunities as measured by the excess return ρ. It thus cuts into profits beyond the mere mechanical effect.

In the present scenario, the ACE tax is refunded to the entrepreneurial sector in order to isolate the efficiency effects. As in the preceding subsection, welfare changes in proportion to dv_E. Given the impact on net of tax expected profits and tax revenue, and noting $\rho = (1-\tau)\left(x_c' - i\right)$, the tax reduces net welfare in proportion to

$$dv_E = d\pi_E + dT_E = -\left(x_c' - i\right) \cdot p s_c I_c \left(\phi_\tau - \phi_\sigma\right) \cdot \hat{\tau} < 0. \tag{28}$$

The mechanical effect merely reflects redistribution from the entrepreneurial to the public sector and cancels in the aggregate. However, the behavioral effect strictly reduces welfare even if tax rates are zero initially! The reason is that even a small tax tightens the financing constraint and reduces investment of firms that earn an above normal rate of return. The size of the welfare loss depends on the weight of innovative firms in the entire business sector, as indicated by $s_c I_c$. In summing up, we state

Proposition 3 (Profit Taxation) *The consequences of a higher rate of a profit tax which is neutral with respect to the user cost of capital, are: (i) the tax is neutral towards investment of standard firms but reduces investment of constrained firms; (ii) it reduces profits of constrained firms relatively more than profits of unconstrained firms and, thereby, discourages innovation; (iii) it leads to a first order welfare loss even for a small rate.*

The impact of the tax in an unconstrained economy where none of the firms is restricted in external funding, is easily recovered by setting the ϕ- and ρ-coefficients to

zero. In this case, traditional theory suggests that the ACE tax is fully neutral. For example, investment of innovative firms in (14) would simply be $\hat{I}_c = u_\lambda \hat{\lambda}$. Neither the tax rate τ, because it does not change the user cost, nor the upfront subsidy σ, because expansion investment is not sensitive to cash-flow, would have any impact on investment. Clearly, individual investments in (25) would be unaffected. Given that the mechanical effect reduces profits of standard and innovative firms as well as R&D costs by the same proportion, innovation would not be affected either since the threshold q in (25) does not change. Consequently, the changes in tax revenue and private expected profit involve only mechanical effects which cancel and leave a zero impact on aggregate welfare. The tax would be fully neutral in an unconstrained equilibrium.

4.3 Revenue Neutral Tax Reform

Starting from an initial equilibrium where R&D spending and financing costs are fully tax deductible ($\tau = \sigma > 0$ and $\lambda = 1$), the following subsections discuss a revenue neutral restructuring of profit taxation that boosts investment, productivity and welfare. Specifically, we will exogenously change λ or σ and compute revenue neutral changes in the tax rate to keep fiscal revenue constant. We show how these policies can be used to relax finance constraints by implicitly redistributing from standard to innovative but financially constrained firms.

4.3.1 Self-financed R&D Tax Credit

In reality, R&D spending on personnel etc. is tax deductible ($\sigma = \tau$), but governments often grant explicit additional subsidies, making $\sigma > \tau$. We show that this policy can potentially encourage private R&D spending and innovation based growth even if it is self-financed with a revenue neutral increase in the tax rate. The policy redistributes towards innovative firms since the higher tax rate extracts revenue from all firms while the subsidy is limited only to those with R&D spending. Set $dT_E = 0$ in (20) and note

$\nabla_T = 0$ as in (21) when an ACE system is in place initially. Using the definition of ρ, the required increase in the tax rate is

$$\hat{\tau} = \epsilon_{\tau,\sigma} \cdot \hat{\sigma}, \quad \epsilon_{\tau,\sigma} \equiv \frac{(1-\sigma)\, kRs_k - \tau\,(x_c' - i)\, ps_c I_c \phi_\sigma}{\bar{\pi} - \tau\,(x_c' - i)\, ps_c I_c \phi_\tau} < 1. \tag{29}$$

Clearly, a higher R&D subsidy requires a higher tax rate to keep revenues constant. The tax rate needs to rise relatively less if the elasticity is smaller than one which is guaranteed if $\pi_E > \tau\,(x_c' - i)\, ps_c I_c\,(\phi_\tau - \phi_\sigma) > 0$. This condition is fulfilled when the tax rate is small, $\tau \to 0$, or if the finance constraint on innovative firms is weak, $x_c' \to i$. The preceding subsection showed that raising tax revenue with an ACE tax ($\hat{\tau} = \hat{\sigma}$) discriminated against innovative and financially constrained firms. By way of contrast, the revenue neutral restructuring of the profit tax in this subsection redistributes in the opposite direction. While the higher tax rate extracts revenue from all firms, the *disproportionate* increase in the subsidy favors innovative firms.

How does the policy affect investment, innovation and welfare? With an ACE system in place, the marginal reform is inconsequential for investment but squeezes profits of unconstrained firms, $\hat{I}_u = 0$ and $d\pi_u = -\pi_u \hat{\tau}$. For constrained firms, (14) implies

$$\hat{I}_c = (\phi_\sigma - \phi_\tau \epsilon_{\tau,\sigma}) \cdot \hat{\sigma} = \frac{(1-\sigma)\, kR - \pi_c \epsilon_{\tau,\sigma}}{mI_c} \cdot \hat{\sigma}. \tag{30}$$

Since $\pi_c - (1-\sigma)\, kR = (1-q)\, \pi_c + q\pi_u > 0$ by the innovation threshold, raising the ACE tax (case $\epsilon_{\tau,\sigma} = 1$) was seen to discriminate against innovative firms and reduce their investment. The present scenario, in contrast, may favor innovative firms and relax their financing constraint since the tax rate rises by a smaller amount. Hence, investment should become less constrained and expand if redistribution is strong enough,

$$(1-\sigma)\, kR - \pi_c \epsilon_{\tau,\sigma} > 0 \quad \Leftrightarrow \quad \chi(q) = \frac{\int_0^q q' dG(q')}{\int_q^1 (1-q')\, dG(q')} = \frac{s_u}{s_k - s_c} > \frac{\pi_c^*}{\pi_u^*}. \tag{31}$$

To see this, get $(1-\sigma)\, kR - \pi_c \epsilon_{\tau,\sigma} = [\bar{\pi} - \pi_c s_k]\,(1-\sigma)\, kR / (\bar{\pi} - \tau\,(x_c' - i)\, ps_c I_c \phi_\tau)$. Note $\pi_j = (1-\tau)\, \pi_j^*$ which holds with an ACE system in place. Using also the definition of $\bar{\pi}$ yields $\bar{\pi} - \pi_c s_k = (1-\tau)\,[s_u \pi_u^* - \pi_c^*\,(s_k - s_c)]$. Hence, the numerator in (30) is positive if the condition in (31) holds. The numerator of χ reflects the average, early-stage *survival*

rate of standard firms while the denominator refers to the average *failure rate* of innovating firms. In our model, innovating firms are more successful and survive to the market more frequently than firms with low productivity. Clearly, the ratio χ increases in the cut-off value q, $\chi'(q) > 0$. If innovation is costly, only few firms will innovate and the probability ratio becomes very large, $\lim_{q \to 1} \chi(q) = \infty$. For any given π_j, we may have a cost k such that the innovation threshold q, given by $(\pi_c^* - \pi_u^*) q = kR$ when an ACE system is in place, comes close to unity. Hence, an equilibrium with relatively few innovating and many standard firms implies a very large probability ratio so that the condition is certainly fulfilled. In this case, a higher R&D subsidy self-financed with a higher profit tax rate indeed redistributes towards innovative firms and thereby relaxes on net their financing constraint, making them invest more, $\hat{I}_c > 0$.

Profits of innovative firms in (15) and the innovation threshold in (16) change by

$$d\pi_c = -\pi_c \cdot \hat{\tau} + \rho p I_c \cdot \hat{I}_c, \quad \hat{q} = -(1 - \epsilon_{\tau,\sigma}) \cdot \hat{\sigma} - \frac{\rho p I_c}{\pi_c - \pi_u} \cdot \hat{I}_c. \tag{32}$$

The innovation threshold strongly falls. This is not only because the policy directly benefits innovative firms ($\epsilon_{\tau,\sigma} < 1$). It also favors them by boosting investment which earns an above normal return. This strengthens profits of innovative relative to standard firms and induces additional innovation.

Since the tax reform is revenue neutral, $dT_E = 0$, welfare of entrepreneurs changes in line with net expected profit, $dv_E = d\pi_E$. Evaluating (18) results in

$$d\pi_E = \left[\left((1 - \sigma) s_k kR - \bar{\pi} \epsilon_{\tau,\sigma} \right) + \rho p s_c I_c \left(\phi_\sigma - \phi_\tau \epsilon_{\tau,\sigma} \right) \right] \cdot \hat{\sigma}. \tag{33}$$

Under the conditions mentioned above, the policy stimulates investment of constrained firms, $\hat{I}_c = (\phi_\sigma - \phi_\tau \epsilon_{\tau,\sigma}) \hat{\sigma} > 0$, which translates into higher expected profit π_E. When starting from an untaxed equilibrium, $\epsilon_{\tau,\sigma} = (1 - \sigma) kR s_k / \bar{\pi}$ so that the first bracket is seen to be zero. A small self-financing R&D subsidy thus boosts expected profit and welfare by the second term. With a positive tax rate, substitute $\epsilon_{\tau,\sigma}$ and use the ϕ-coefficients in the numerator to get

$$(1 - \sigma) s_k kR - \bar{\pi} \epsilon_{\tau,\sigma} = (\bar{\pi} - \pi_c s_k) \cdot \frac{\tau (x_c' - i) p s_c (1 - \sigma) kR/m}{\bar{\pi} - \tau (x_c' - i) p s_c I_c \phi_\tau},$$

which is positive as shown in the line following (31). Hence, with few innovative and many standard firms, the condition on $\chi(q)$ is satisfied so that a self-financed R&D subsidy is welfare improving. If all firms were unconstrained, all coefficients in (33) would be zero. In the absence of financial frictions, the ACE system would support a Pareto-optimal allocation so that a marginal, self-financed increase in the R&D subsidy would have a zero welfare effect!

Proposition 4 (R&D Tax Credit) *A revenue neutral increase in the R&D tax credit, leading to a subsidy larger than the tax rate, (i) redistributes towards innovative and constrained firms and boosts innovation. (ii) If there are relatively few innovative firms, the tax credit also stimulates investment of constrained firms and, (iii) yields first order welfare gains relative to non-discriminatory taxation.*

4.3.2 Tax Cut Cum Base Broadening

This subsection shows how an apparently non-discriminatory tax can redistribute between more and less profitable firms. For example, tax cut cum base broadening restricts interest deductions (lower λ) to broaden the tax base and uses the extra revenue to cut the tax rate. While restricting interest deductions hurts all firms, the tax cut favors innovative firms relatively more than standard ones. On net, we find that the revenue neutral policy redistributes from standard towards innovative firms. In reducing their tax liability, it relaxes the financing constraint and boosts investment and profits of innovative firms and thereby induces more firms to spend on R&D. The policy yields a welfare gain that reflects the excess return on constrained investment.

Limiting interest deductions $\hat{\lambda} < 0$ broadens the tax base and allows for a lower tax rate such that fiscal revenue stays constant, $dT_E = 0$. When an ACE system is in place ($\sigma = \tau$ and $\lambda = 1$), the initial equilibrium implies $\pi_j = (1-\tau)\,\pi_j^*$ which leads to $\bar{\pi} = (1-\tau)\,\bar{\pi}^*$ and $T_E = \tau\,(\bar{\pi}^* - s_k kR)$. Evaluating (20), noting (14), and using $\nabla_T = 0$

as shown in (21) yields

$$\hat{\tau} = \epsilon_{\tau,\lambda} \cdot \hat{\lambda}, \quad \epsilon_{\tau,\lambda} \equiv \tau \cdot \frac{pi\bar{I} - (x_c' - i)\, ps_c I_c \cdot (u_\lambda + \phi_\lambda)}{\bar{\pi} - \tau\,(x_c' - i)\, ps_c I_c \cdot \phi_\tau}. \tag{34}$$

Since $u_\lambda + \phi_\lambda = \tau ip/m$, the elasticity $\epsilon_{\tau,\lambda}$ is clearly positive as long as the excess return and the tax rate are not too large.

Although applying the same rules to all firms, the policy effectively discriminates, i.e., redistributes from standard towards constrained innovative firms. This is most easily seen by starting first with the direct, *mechanical* effect of the policy when investment remains fixed. In this case, (34) implies a revenue neutral cut in the tax rate equal to $\hat{\tau} = \left(\tau pi\bar{I}/\bar{\pi}\right)\hat{\lambda}$. In consequence, a firm's expected tax liability $pT_j = \tau p\,(x_j - \lambda_j iI_j)$ changes by $pdT_j = \pi_j\hat{\tau} - \tau piI_j\hat{\lambda}$ or, upon substitution, $pdT_j = \tau piI_j\left(\bar{I}/\bar{\pi}\right)\left(\pi_j/I_j - \bar{\pi}/\bar{I}\right)\hat{\lambda}$. The rent per unit of capital is larger for constrained firms,[12] so that $\pi_c/I_c > \bar{\pi}/\bar{I} > \pi_u/I_u$, where $\bar{\pi}/\bar{I}$ is an average.[13] Hence, the mechanical effect reduces the tax liability of constrained firms and raises it for others so that tax revenue remains constant on average, $dT_c < 0 < dT_u$. If all investment were unconstrained, $x_c' = i$ and $\pi_j/I_j = \bar{\pi}/\bar{I}$, there would be no redistribution across firms. Turning to the *behavioral* impact, we find that a lower deduction ($\hat{\lambda} < 0$) raises the user cost while the reduction in the tax rate has no impact. On net, the policy harms investment of standard firms. The lower tax liability of innovative firms relaxes their financing constraint and boosts investment, leaving an asymmetric investment response, $\hat{I}_c > 0 > \hat{I}_u$. Taking account of the behavioral effect, the total change in the tax rate is a magnification of the direct, mechanical effect without tax base adjustment if $\epsilon_{\tau,\lambda} > \tau pi\bar{I}/\bar{\pi}$. This condition holds if $(x_c' - i)\, ps_c I_c \tau\left[\tau pi\bar{I}\phi_\tau - \bar{\pi}\,(u_\lambda + \phi_\lambda)\right] > 0$.

[12] The average rent per unit of capital is $\tilde{\pi}(I_j) \equiv (1-\tau)\left[\theta_j f(I_j) - uI_j\right]/I_j$ and, by concavity, satisfies $\tilde{\pi}'(I_j) = -(1-\tau)\,\theta_j\left[f(I_j) - I_j f'(I_j)\right]/I_j^2 < 0$. Unconstrained investment satisfies $\theta_j f'\left(I_j^*\right) = u$. With isoelastic technology $f(I) = I^\alpha$, $0 < \alpha < 1$, investments are $I_j^* = (\theta_j\alpha/u)^{1/(1-\alpha)}$ so that *average rent* is independent of θ_j, $\tilde{\pi}\left(I_j^*\right) = (1-\tau)\,u\,(1-\alpha)/\alpha$. If all firms are unconstrained, the productive ones invest more but have the same rent $\tilde{\pi}$ per unit of capital. However, since $\tilde{\pi}'(I_j) < 0$, the average rent of high productivity firms rises when investment gets constrained *below* the optimal level, implying $\tilde{\pi}_c > \tilde{\pi}_u$.

[13] Write $\bar{\pi}/\bar{I} = \left(s_c I_c/\sum_j s_j I_j\right)\cdot \pi_c/I_c + \left(s_u I_u/\sum_j s_j I_j\right)\cdot \pi_u/I_u$.

After substituting the ϕ-coefficients, this is equivalent to

$$\epsilon_{\tau,\lambda} > \frac{\tau pi\bar{I}}{\bar{\pi}} \quad \Leftrightarrow \quad (x_c' - i)\, ps_c I_c \tau \cdot \frac{\tau ip\bar{I}}{m}\left[\frac{\pi_c}{I_c} - \frac{\bar{\pi}}{\bar{I}}\right] > 0. \tag{35}$$

The expression in the square bracket is positive since the rent per unit of capital is larger for constrained firms as noted above. If all investment were unconstrained, $\pi_j/I_j = \bar{\pi}/\bar{I}$, there would be no magnification effect, leaving $\epsilon_{\tau,\lambda} = \tau pi\bar{I}/\bar{\pi} > 0$ only.

Investment of standard firms does not depend on the tax rate since the tax does not affect the user cost at the outset. However, restricting interest deductions harms investment by $\hat{I}_u = u_\lambda \hat{\lambda} < 0$ as in (11). In contrast, since the tax cut cum base broadening policy redistributes towards innovative firms, it relaxes their financing constraint and boosts investment (evaluate 14 and use the ϕ-coefficients) if

$$\hat{I}_c = [u_\lambda + \phi_\lambda - \phi_\tau \epsilon_{\tau,\lambda}] \cdot \hat{\lambda} = -\frac{\pi_c \epsilon_{\tau,\lambda} - \tau piI_c}{mI_c} \cdot \hat{\lambda} > 0 \quad \Leftrightarrow \quad \frac{\pi_c}{I_c} > \frac{\bar{\pi}}{\bar{I}}. \tag{36}$$

To see the sign restriction, note the magnification effect $\epsilon_{\tau,\lambda} > \tau pi\bar{I}/\bar{\pi}$. The numerator thus yields $\pi_c \epsilon_{\tau,\lambda} - \tau ipI_c > \pi_c \cdot \tau pi\bar{I}/\bar{\pi} - \tau piI_c = \tau piI_c \left[\pi_c/I_c - \bar{\pi}/\bar{I}\right] \left(\bar{I}/\bar{\pi}\right) > 0$. Since (35) must hold, the revenue neutral reform boosts innovative firm investment.

The pure mechanical effect redistributes and shifts profits from standard to innovative firms. By the envelope theorem, the reduction in standard investment has no further effect on profits of unconstrained firms. In stimulating constrained investment which earns an excess return, the policy additionally favors profits of innovative relative to standard firms. R&D clearly becomes more attractive, leading to a falling innovation threshold,

$$\hat{q} = (\zeta_\tau \epsilon_{\tau,\lambda} - \zeta_\lambda) \cdot \hat{\lambda} < 0 \quad \Leftrightarrow \quad \pi_c/I_c > \bar{\pi}/\bar{I} > \pi_u/I_u. \tag{37}$$

To prove this, use $\epsilon_{\tau,\lambda} > \tau pi\bar{I}/\bar{\pi}$, substitute the ζ- and ϕ-coefficients and get

$$\zeta_\tau \epsilon_{\tau,\lambda} - \zeta_\lambda > \tau pi\left[\frac{\bar{I}}{\bar{\pi}} - \frac{I_c - I_u}{\pi_c - \pi_u}\right] + \frac{\rho pI_c}{\pi_c - \pi_u}\frac{\tau pi}{m}\frac{\bar{I}}{\bar{\pi}}\left[\frac{\pi_c}{I_c} - \frac{\bar{\pi}}{\bar{I}}\right] > 0,$$

where $\bar{I}/\bar{\pi} - (I_c - I_u)/(\pi_c - \pi_u) = \left[\left(\pi_c/I_c - \bar{\pi}/\bar{I}\right) I_c\bar{I} + \left(\bar{\pi}/\bar{I} - \pi_u/I_u\right) I_u\bar{I}\right] / \left[(\pi_c - \pi_u)\,\bar{\pi}\right]$ is positive in the constrained equilibrium. In the unconstrained case, $\epsilon_{\tau,\lambda} = \tau pi\bar{I}/\bar{\pi}$ and

$\rho = 0$ so that the above equation would become $\zeta_\tau \epsilon_{\tau,\lambda} - \zeta_\lambda = \tau pi \left[\frac{\bar{I}}{\bar{\pi}} - \frac{I_c - I_u}{\pi_c - \pi_u} \right] = 0$ since average rents π_j / I_j would be identical across firm types. Again, the same policy would have no impact on innovation in the absence of financing constraints.

Finally, given revenue neutrality, welfare changes in proportion to net expected profit. Evaluating (18) and using $\hat{\tau} = \epsilon_{\tau,\lambda} \hat{\lambda}$ yields

$$d\pi_E = -\left[\left(\epsilon_{\tau,\lambda} - \tau pi \bar{I}/\bar{\pi} \right) \bar{\pi} + \rho p s_c I_c \cdot \left(\phi_\tau \epsilon_{\tau,\lambda} - u_\lambda - \phi_\lambda \right) \right] \cdot \hat{\lambda} > 0, \tag{38}$$

where $\phi_\tau \epsilon_{\tau,\lambda} - u_\lambda - \phi_\lambda > 0$ was already shown in (36) while the magnification effect $\epsilon_{\tau,\lambda} > \tau pi \bar{I}/\bar{\pi}$ holds by (35). Hence, all terms in the square bracket are positive in the constrained equilibrium. The tax cut cum base broadening policy thus boosts welfare. The unconstrained equilibrium, in contrast, is characterized by $\epsilon_{\tau,\lambda} = \tau pi \bar{I}/\bar{\pi}$ and $\rho = 0$, implying a zero welfare effect to the first order. The welfare result is intuitively clear when recognizing that the only distortion in the present model is the financing constraint on expansion investment of innovative firms. Since the policy relaxes this constraint, it allows for more investment of innovative firms and, thereby, creates net income gains in proportion to the excess return of these companies.[14]

Proposition 5 (Tax Cut Cum Base Broadening) *Starting with undistorted user costs of capital, a smaller deduction of financing costs and a revenue neutral cut in the tax rate redistributes towards innovative firms and (i) boosts innovation; (ii) raises (reduces) investment of constrained (unconstrained) firms; and (iii) raises welfare.*

5 Conclusions

Even in advanced economies with a well developed financial sector, many firms – and typically the most innovative ones – tend to be financially constrained for several reasons.

[14] Substituting coefficients, we can show the first term in (38) to be proportional to the excess return,

$$\epsilon_{\tau,\lambda} - \tau pi \bar{I}/\bar{\pi} = \left(x_c' - i \right) \tau \frac{p s_c I_c \left(\pi_c / I_c - \bar{\pi}/\bar{I} \right) \tau pi \bar{I}/m}{\left[\bar{\pi} - \left(x_c' - i \right) p s_c I_c \cdot \tau \phi_\tau \right] \bar{\pi}}.$$

First, they often spend considerable resources on R&D which drains own funds available for self-financing of equipment investment and restricts external leverage. Secondly, because they are more innovative, they have more profitable investment opportunities and need large external funds to grow. Finally, these firms are often closely held companies driven by entrepreneurs who possess key technological know-how and inalienable human capital. Since their input is essential for the development of the company, they must keep a large enough stake to assure full effort and commitment to the firm. However, the entrepreneur's stake subtracts from pledgeable income that can be promised to external investors as a credible repayment and thereby limits the firm's financing capacity. In contrast to standard firms, innovative growth companies often earn a return in excess of the user cost of capital because the restricted access to external finance prevents them from fully exploiting the opportunities to invest. Stimulating investment of constrained firms thus boosts income and welfare in the economy.

The presence of finance constrained firms has important implications for tax policy. While taxes affect investment of standard firms via the traditional user cost channel, user costs and effective marginal tax rates are not directly relevant for constrained firms. Instead, investment becomes sensitive to future cash-flow, own internal resources, or institutional characteristics such as the quality of a country's legal system which determines accountability and discretion of owner-managers. In this paper, we have proposed a framework of heterogeneous firms where an early stage R&D decision endogenously divides the business sector into constrained and unconstrained firms. We have found, among others, the following novel results on the effects of business taxation: First, R&D subsidies not only encourage innovation but also relax financing constraints and help innovative firms to exploit investment opportunities to a larger extent. Second, introducing a profit tax which would be neutral according to the traditional user cost theory, restricts expansion investment of constrained firms by reducing pledgeable cash-flow and thereby discourages innovation. Even a small tax leads to a welfare loss that is proportional to the excess return on investment of constrained firms. Third, a revenue neutral increase in profit taxes to finance larger R&D subsidies redistributes towards innovative firms, relaxes their

finance constraint, and may boost aggregate productivity and welfare. Finally, even an apparently non-discriminatory tax reform can systematically redistribute among firms in different financial regimes. In this vein, we found that a revenue neutral tax cut cum base broadening policy redistributes towards constrained innovative firms and thereby stimulates constrained investment, leading to more innovation and higher welfare.

Appendix

A Capital and Output Markets: Supply and demand for loanable funds are in equilibrium if $A(1-E)+A_c(s_k-s_c)E+A(1-s_k-s_u)E=\sum_j(I_j-A_j)s_jE+\sigma k s_k E+Z$. The left hand side states supply of funds consisting of (i) savings of $1-E$ investors; (ii) residual savings $A_c=A-(1-\sigma)k$ of failed innovators; and (iii) savings A of failed standard firms. Demand on the right hand side consists of (i) credits to both types of firms; (ii) public debt to pay R&D subsidies at the beginning of period; and (iii) investments in international bonds or in a safe Z-technology. Rearranging yields

$$A-K\cdot E=Z,\quad K\equiv s_k k+\sum_j s_j I_j, \tag{A.1}$$

where K denotes total investment per firm. If r is the fixed productivity of a safe Ricardian technology, then Z is residual savings invested in the Ricardian sector. If r is an internationally fixed deposit rate, Z denotes capital exports or imports, depending on whether national savings A exceed or fall short of national investments KE.

Private consumption is equal to end of period wealth of investors and entrepreneurs, $Y=(AR+\pi_E+T_E)E+AR(1-E)$. Substituting π_E and T_E and other definitions such as $\pi_j+pT_j=p(I_j+x_j)-I_jR$ and K, defining aggregate output of the entrepreneurial sector $X\equiv\sum_j p(I_j+x_j)s_jE$, and using (A.1) yields output market clearing $Y=ZR+X$. If ZR is end of period output from investments in the Ricardian technology, then consumption Y is equal to aggregate sectoral output. Alternatively, the output market condition can be stated as $Y-X=ZR$ where imports $Y-X$ are paid by foreign source earnings on capital exports Z.

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