Economic Policy and The Financing of Innovation

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Abstract

Adverse selection in the financing of innovation limits the rate of technological progress and slows down economic growth. To formalize this fact, I develop a model of Schumpeterian Growth wherein outside investors cannot screen entrepreneurs from a crowd of non-entrepreneurial imitators. Therein, I study the design of optimal policy and the effects of policy reforms on technological progress. Because networth allows entrepreneurs to invest in their own projects and detract imitators by raising the costs to imitation, policy reforms that increase entrepreneurial networth boost technological progress even when financed through a higher tax on profits. Since entrepreneurs pursue innovation to make a profit, if it were not for the adverse selection problem, a higher tax on profit would harm technological progress. Taxing consumption is an effective way to raise networth and subsidize profits simultaneously. If the government taxes consumption sufficiently, it is able to implement the socially optimal level of technological progress free of adverse selection. Otherwise, the government may prefer to implement a second-best allocation with adverse selection. This happens when boosting networth enough to avoid adverse selection requires taxing profits excessively.

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1 Introduction

The private and social gains from technological research diverge in the presence of externalities in the production and dissemination of innovation. The policy prescription of the endogenous growth literature is simple: subsidize innovation activity sufficiently to eliminate that wedge. However, there is substantial evidence that firms in economies at all stages of development face constraints in financing the pursuit, adoption, or acquisition of innovations.\(^1\) In the presence of financial frictions, providing incentives is neither necessary nor sufficient for a policy to promote innovation activity, because a policy must also alleviate the constraints induced by the financial frictions. By introducing an information asymmetry between potential innovators and outside investors into an otherwise standard model of Schumpeterian growth, I study how adverse selection impacts what kind of government policy is effective at promoting technological research.

To this end, I incorporate adverse selection in the financing of innovation into a Schumpeterian growth model in the following simple way. A fraction of untalented consumers can imitate the research effort of entrepreneurs and earn a private benefit that increases with project size. Entrepreneurial networth and research effort determine whether entrepreneurs must compete with imitators in the credit market. Because a high research effort to networth ratio attracts imitators, entrepreneurs face a tradeoff between the cost of capital and innovation scale.

I show that increasing the networth of entrepreneurs is necessary to increase technological research while at the same time avoiding an equilibrium with adverse selection. In the model, the investable networth of entrepreneurs and their potential imitators equals their after-tax labor income, while an entrepreneur’s incentive to pursue research depends on the after-tax profits he expects to earn. Boosting networth provides a rationale for taxing business profits in order to subsidize labor income. This starkly contrasts the standard Schumpeterian growth model, wherein taxing business profits could only result in a decrease in research. Substituting labor income taxes with profit taxes is not wholly effective, however, because eventually entrepreneurs become unconstrained by their relatively high networth and poor incentives. At this point, the benchmark and adverse selection models behave identically, and further increases in the profit tax are growth-reducing.

Substituting labor income and profit taxes for consumption taxes, i.e. fundamental tax reform, more decidedly boosts technological research. Consumption taxes do not hurt the incentive to innovate, as profit taxes do, nor do they constrain the entrepreneur’s effort choice, as labor income taxes do. In fact, when the government can freely tax consumption, it is

\(^1\)Fagerberg, Srholec, and Verspagen (2010) and Hall and Lerner (2010) recently reviewed this evidence.
able to implement the first-best level of technological research. Otherwise, the government must tax profit and labor income more and implement a second-best equilibrium at a lower level of research.

Surprisingly, if the government is unable to tax consumption sufficiently, the second-best equilibrium exhibits adverse selection. Although adverse selection wastes resources, admitting adverse selection also allows the government to tax income more heavily to subsidize profits and thus promote technological research. This happens because implementing an equilibrium free of adverse selection requires a low tax on labor income, which given a low tax on consumption requires a high tax on profit to balance the government’s budget. When the government is unable to tax consumption sufficiently, the cure for adverse selection is worse than the disease.

I also consider an alternative model with moral hazard in the financing of innovation. Moral hazard constrains the entrepreneur’s choice of research effort by limiting the fraction of profits he can commit to pay outsiders if he successfully innovates. While profits are imperfectly pledge-able, labor income is perfectly pledge-able. So, if the entrepreneur cannot commit to share enough of his profits, taxing profits to subsidize labor income boosts technological research by increasing the entrepreneur’s ability to pledge resources to his project. Nonetheless, as in the model of adverse selection, raising tax revenues from consumption taxes to simultaneously subsidize profits and labor income is a more effective way to boost research effort. Although it is necessary that the moral hazard problem bind for a policy of taxing profits to subsidize labor income to increase technological research, it is not sufficient. When the aggregate rate of innovation is high and entrepreneurs make up a small fraction of the labor force, entrepreneurs bear most of the profit tax burden and little of the labor income tax burden. In this case, taxing profits to subsidize labor income harms the entrepreneur’s ability to pledge resources to his project.

The relationship between tax policy and economic growth in the presence of adverse selection has up to now remained undeveloped. Plehn-Dujowich (2009) develops a model of endogenous growth with adverse selection to measure the negative impact of adverse selection on economic growth, but unlike this paper, does not consider policy. García-Peñalosa and Wen (2008) assume entrepreneurs must take un-diversifiable risks, and Aghion and Bolton (1997) assume entrepreneurs face a moral hazard problem\(^2\) in growth models designed to show the growth benefits of redistributive tax policies. This paper is instead concerned with the differential effects of taxing various sources of economic activity. The financial

\(^2\)The moral hazard problem in Aghion and Bolton (1997) stems from the hidden effort choice of the entrepreneur and the inability of outside creditors to claim more than the entrepreneur’s net worth (at the time the project is completed) as payment (limited liability).
development and economic growth literature (reviewed by Levine (1997)), has incorporated financial frictions into endogenous growth models to understand, on the one hand, how the frictions affect economic growth and welfare, and on the other hand, how financial institutions reduce these imperfections by providing risk-sharing, screening, and monitoring services. However, the policy focus of that literature has been to estimate the effects of government policies that induce financial institutions to provide more of their services, and how these policies can have long-lasting effects as they allow the economy to develop. Instead, I ask how well the government can pursue policy despite the persistence of financial frictions.

The paper is structured as follows. Section 2 reviews the standard Schumpeterian Growth model which underlies the analysis. Section 3 develops the model with adverse selection, and analyzes the effects of small policy reforms. Section 4 studies the optimal policy problem. Section 5 considers a model with moral hazard. The last section concludes. Appendix A completes the description of the standard Schumpeterian growth model of section 2. Appendix B provides proofs to the lemmas and propositions within the paper.

2 A Benchmark Model of Schumpeterian Growth

The basic structure of the economy imperfectly follows chapter 4.3 in Aghion and Howitt (2009).

There are three types of tradable goods: consumption, a unit continuum of intermediate products, and a unit continuum of industry-specific labor inputs. The intermediate goods perish each period while the consumption good is long-lived, but fully depreciates if used to produce intermediate goods. There are two types of agents, entrepreneurs and consumers. Each agent lives two periods, is able to provide a unit of industry-specific labor effort in his first period of life, and maximizes expected consumption. While any agent can start a business, only entrepreneurs are capable of pursuing technological research.

![Figure 2.1: Benchmark Model Timeline](image)
At the beginning of period $t$, in each industry one entrepreneur and $L - 1$ consumers are born. Also present are one entrepreneur and $L - 1$ consumers born in period $t - 1$. The old entrepreneurs and consumers that started businesses in $t - 1$ produce intermediate goods. Each industry is monopolized by a single producer. When the industry just innovated, the monopoly is held by the old entrepreneur, otherwise it is held by a random consumer.\footnote{Think of this consumer as the descendant of the last entrepreneur to innovate; he lacks entrepreneurial talent and behaves as a consumer.}

A perfectly competitive sector produces the consumption good, employing the entire spectrum of industry-specific labor and intermediate goods. From the consumption good producers, the young agents receive a wage and the intermediate good producers receive payments for their goods. In turn, old agents who invested at $t - 1$ in the intermediate good producers receive the return on their investment.

At this point in the timeline, the only good trading in the economy is the consumption good. Young entrepreneurs choose how much of it to invest in research. Afterward, the outcome of research is revealed. Also, the technologically superior producer at $t$ passes on his knowledge to a young consumer. Then, the technologically superior producer at $t + 1$ will either be the young entrepreneur at $t$ if he innovated or the young consumer who inherited the best technology at $t$. The young entrepreneurs and consumers now decide how much of the consumption good to invest in production of the intermediate good, while the old consume and die. The young consume the remainder of the stock not invested in intermediate good production or research.\footnote{They could also store the consumption good, but since the agents are indifferent between consumption and storage I ignore this issue.} Period $t$ ends, and period $t + 1$ begins with the birth of a new generation of agents.

Uniformly throughout the model, industry variables are denoted by a capital Roman letter with an index $i$, e.g. $X_i$. Industry variables adjusted by industry frontier productivity $A_i$ are denoted by the lower case, e.g. $x_i \equiv X_i/A_i$. Economy-wide averages drop the index, e.g. $X \equiv \int X_i di$, and average (or aggregate) variables adjusted for average productivity are denoted by the lower case without the index, e.g. $x \equiv X/A$. Gross rates of growth are denoted $g_{t+1}^X \equiv \frac{X_{t+1}}{X_t}$.

In this section I intend only to explain the key ingredients of the innovation process necessary to develop and understand the results of this paper. For a complete description of the benchmark model, refer to appendix A. Throughout the paper, I only consider equilibria with a net interest rate equal to zero ($r = 0$) to simplify the analysis.
2.1 The Set of Policy Instruments

Suppose the government employs a time-invariant set of tax schedules on labor, consumption, and profit. I express taxes as proportional rates, so that tax burdens vary linearly with agents’ choices and the analysis remains tractable. Notably, I do not allow for taxes on capital gains, production, or investment. Including a very large set of taxes would distract the reader from the main points of this paper, without enough additional insights. A capital gains tax is similar to a profit tax; they both reduce an entrepreneur’s incentive to pursue research. Production taxes, by manipulating the revenue and cost of producing intermediate goods, would be able to rectify the appropriability problem caused by monopoly power by aligning the marginal cost of investment to its marginal product. The static benefit of subsidization of monopolistic production is a well known result and it does not interact in an interesting way with the messages of the paper. A tax on investment causes the interest rate to rise; it reduces the incentive to pursue research or to produce intermediate goods by lowering the present value of future profits. A profit tax has a similar effect on research effort without affecting production (and thus avoids unnecessarily complicating the analysis).

The government budget constraint plays a crucial role in this paper. How the government finances a policy is just as important as the policy itself. Excluding taxes on capital gains, production, and investment restricts the government’s sources of revenue and forces a stricter tradeoff between labor, consumption, and profit taxation. In reality, these tradeoffs could be more flexible. However, including more tax rates would not undo the results of the paper, rather it would lead to a richer set of results of which the results of this paper would be a subset.

I assume all agents are taxed at equivalent rates and denote the set of tax rates by $\tau$. An element of the set receives a subscript representative of the item it taxes: $w$ for labor income, $\pi$ for profit, and $c$ for consumption. More concisely, $\tau = \begin{pmatrix} \tau_\pi \\ \tau_w \\ \tau_c \end{pmatrix}$. The government cannot require a payment higher than the labor income or profit being taxed, i.e. $\tau_w, \tau_\pi, \in (-\infty, 1]$. Additionally, if the tax rates were so generous as to imply a negative price of consumption the agents would choose to consume unboundedly, so in order for an equilibrium to exist it must be that $\tau_c \in [-1, \infty)$.

The equilibrium concept for the game between the government and the agents is standard Nash Equilibrium with a first-move advantage for the government. The government first submits a time-invariant schedule of tax rates $\tau$. Second, the agents choose their best responses to the government’s tax plan.
2.2 Research and Innovation

If the young entrepreneur commits $Z_{it}$ consumption goods to research, the technology of industry $i$ at time period $t + 1$ obeys

$$ A_{i,t+1} = \begin{cases} \gamma A_{it} & \text{with prob. } \mu \left( \frac{Z_{it}}{A_{it}} \right) \\ A_{it} & \text{with prob. } 1 - \mu \left( \frac{Z_{it}}{A_{it}} \right) \end{cases}, $$

where $\mu \left( \frac{Z_{it}}{A_{it}} \right)$ is an increasing concave function of its argument, $\mu (0) = 0$, $\mu (\infty) \rightarrow$ and $\gamma > 1$. If the entrepreneur innovates, he earns the monopoly profit $\Pi_{i,t+1}$ in the second period; otherwise, his profit is zero. So, the entrepreneur chooses research effort to maximize the pre-consumption-tax net present value (NPV) of the project,

$$ NPV_{it} (z_{it} | \tau) \equiv \mu \left( \frac{Z_{it}}{A_{it}} \right) \Pi_{i,t+1} (1 - \tau_{\pi}) - Z_{it}. $$

Because an innovating producer advances a step $\gamma$ in productivity, and given that the solution to the intermediate good producer’s problem implies productivity-adjusted profits across industries are constant (see details in appendix A), adjusting $NPV_{it}$ for productivity $A_{it}$ implies

$$ npv_{it} (z_{it} | \tau) = \mu (z_{it}) \pi_{t+1} (1 - \tau_{\pi}) - z_{it}. $$

The entrepreneur’s optimal choice of productivity-adjusted effort satisfies the first-order condition,

$$ 1 = \mu' (z_{it}) \gamma \pi_{t+1} (1 - \tau_{\pi}), $$

and is hence constant across industries. I now drop the $i$ subscript.

All else equal, lowering the tax rate on profit encourages research. The consumption tax rate has no effect on research because it symmetrically affects the costs and benefits of the decision. Because capital markets are perfect, the research effort decision is independent of the entrepreneur’s wealth, and consequently the labor tax rate does not impact research effort.

The evolution and rate of growth of average productivity are

$$ A_{t+1} = \mu (z_{t}) \gamma A_{t} + (1 - \mu (z_{t})) A_{t} = (1 + \mu (z_{t}) (\gamma - 1)) A_{t} $$

$$ g_{t+1}^A = 1 + \mu (z_{t}) (\gamma - 1). $$

The growth rate of productivity increases for two reasons, the step size of innovations is
larger or entrepreneurs allocate more resources to technological research. If entrepreneurs do not put any effort into research, \( z_t = 0 \) and productivity does not grow.

2.3 Aggregation and The Government Budget Constraint

Aggregation is considerably simplified by the linear dependence of industry-specific variables on productivity. Aggregate variables divided by the economy’s average productivity are equivalent to the industry-specific productivity-adjusted values of the same variables, which are constant across industries.

The analysis in this paper restricts itself to comparisons across balanced growth paths. On a balanced growth path, all variables grow at the same rate as productivity,

\[
g \equiv 1 + \mu(z)(\gamma - 1),
\]

equal to the growth rate of average productivity. The equilibrium conditions on a balanced growth path are equivalent to the dynamic equilibrium conditions without time subscripts. I omit time subscripts from now on.

Let \( x \) denote the taxable flows. Taxable flows equal the population of agents partaking in each activity multiplied by the economic value of the action being taxed. There is a unit measure of entrepreneurs, each making productivity-adjusted profits \( \pi \), and there are \( L \) agents working in each industry, each earning productivity-adjusted labor income \( w \). Productivity-adjusted aggregate consumption \( c \) satisfies

\[
c(z) = y - i(z) - z,
\]

where \( y \) is aggregate output and \( i(z) \) is the (productivity-adjusted) quantity of consumption goods invested into the production of next-period consumption goods.\(^5\) Consequently, \( x = \begin{pmatrix} \pi & Lw & c \end{pmatrix}' \).

A set of tax schedules must imply net tax transfers that satisfy the government budget constraint, \( \tau x = 0 \). Or, written out explicitly,

\[
\pi \tau_\pi + \tau_w Lw + \tau_c c = 0.
\]

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\(^5\)This assumes, without loss of generality, that any consumption good left over after research and investment is immediately consumed. See appendix A for a derivation of \( y \) and \( i(z) \).
3 A Model of Adverse Selection

Adverse selection increases the cost of externally financing innovation. An entrepreneur is forced to tradeoff gains from a more intense research pace with the cost of having to compensate outsiders for the chance of lending to imitators without entrepreneurial talent. Thus, an entrepreneur may choose a low level of research effort with a correspondingly low cost of capital, appearing unconstrained when in reality the entrepreneur is avoiding the negative impact of a larger project on his cost of capital. The source of adverse selection is an asymmetric information problem that impedes outsiders from screening the entrepreneur from a crowd of non-entrepreneurial imitators. Imitators earn a private benefit from pursuing wasteful projects that appear to possess the capacity to yield innovations. The share of research capital provided by the entrepreneur affects the desirability of imitation, since imitators must replicate the same leverage ratio as the entrepreneur. By choosing a low leverage ratio, entrepreneurs can strategically avoid imitation, at the expense of scale.

The intuition of this setup is akin to Leland and Pyle (1977). Therein, because self-investment limits an entrepreneur’s ability to diversify, the entrepreneur can credibly signal the quality of his project by owning a larger share of its equity. In my setup, because relying of outside financing can attract imitators, cause adverse selection, and hence raise the entrepreneur’s financing costs, the entrepreneur can credibly signal the quality of his project by contributing a large enough share of the research capital.

In what follows, I express all variables in productivity-adjusted terms and drop the time and industry subscripts.

3.1 The Imitator’s Problem

When the government is unable to observe entrepreneurial talent, non-entrepreneurs are able to imitate research effort while actually receiving part of that effort as a private benefit. To fix ideas, suppose that $N-1$ consumers in each industry can pretend to do research. They cannot possibly succeed because they have no entrepreneurial talent. However, given an entrepreneur’s effort choice $z$, the imitating consumers can also spend $z$, of which they divert a fraction $\theta \in [0, 1]$ as a non-taxable private benefit and the rest is lost. The imitating consumer receives the private benefit when he is old. By replicating research effort $N$ times without incrementing the probability of an innovation occurring, adverse selection wastes resources. Additionally, by raising the cost of capital, adverse selection hurts the incentive

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of entrepreneurs to pursue research.

Assume that the private benefit of the imitator is not taxable as income. The consumer’s value of imitation equals the value of imitation minus the investment cost,

\[ \theta z - (1 - \tau_w) w. \]

The consumption tax rate does not affect the imitation decision because it affects the decision’s benefits and costs symmetrically.

In equilibrium, consumers imitate if and only if \( \theta z - (1 - \tau_w) w > 0. \) A higher research effort on the part of entrepreneurs increases the private benefit to imitating consumers. On the other hand, when an entrepreneur chooses research effort sufficiently close to his own networth, the value of imitation is negative. Adverse selection can only be a concern when entrepreneurs attempt to spend more on research than what they could fund themselves.

### 3.2 The Entrepreneur’s Problem

The entrepreneur must decide whether to pursue less research but avoid adverse selection or choose a higher research effort with adverse selection\(^7\). The decision hinges on the relative benefit of a higher probability of innovation versus the higher costs of financing that adverse selection entails. With \( N - 1 \) imitators, outsiders require a payment \( N/\mu \) from any borrower to compensate for the risk of loaning to an imitator. The maximum research effort the entrepreneur can pursue without having to pay an adverse selection premium is

\[ \bar{\theta} z \equiv (1 - \tau_w) \frac{w}{\theta}. \]  

This threshold condition implies the following property:

**Lemma 1.** An increase in the tax rate on labor income \( \tau_w \) lowers the threshold level of research effort \( \bar{\theta} \). In other words, the interval of research effort choices \([0, \bar{\theta}]\) over which the entrepreneur would not pay an adverse selection premium narrows. As the tax becomes confiscatory, \( \tau_w \to 1 \), the entrepreneur is forced to finance the project with adverse selection, since \( \bar{\theta} \to 0 \).

A higher labor tax reduces the opportunity cost of imitation. When labor taxes increase, the untaxed private benefit of imitation becomes more attractive relative to the after-tax investment the imitator must make in order to imitate the entrepreneur.

\(^7\)If the entrepreneur chose to imitate a consumer, he would receive just his labor income. Because that is equivalent to choosing not to pursue any research, the entrepreneur would never want to imitate the consumer.
The productivity-adjusted net present value of an entrepreneur’s project, \( npv \), is given by

\[
npv(z | \tau) \equiv \begin{cases} 
\mu(z) \gamma (1 - \tau_\pi) \pi - [N (z - (1 - \tau_w) w) + (1 - \tau_w) w], & z > \bar{z}(\tau) \\
\mu(z) \gamma (1 - \tau_\pi) \pi - z, & z \leq \bar{z}(\tau).
\end{cases}
\]

The expression for \( npv \) when \( z > \bar{z}(\tau) \) accounts for the higher marginal cost of outside financing. Note there is a discrete fall in NPV, given by \(- (N - 1) (\bar{z} - (1 - \tau_w) w)\), upon crossing the threshold \( \bar{z} \).

### 3.2.1 Solution Cases

The solution to the entrepreneur’s optimal effort problem has three cases, where the entrepreneur’s choice of effort is either below, equal to, or above \( \bar{z} \). If his choice is below \( \bar{z} \), it must be that the adverse selection problem is irrelevant. The entrepreneur is unconstrained. If his choice is equal to \( \bar{z} \), it must be the entrepreneur would [weakly] like to increase his research effort but is unwilling to pay the adverse selection premium. The entrepreneur is said to be strategically constrained, in the sense that even if he does not pay the adverse selection premium, his choice is affected by it. Last, if his choice is above \( \bar{z} \), the entrepreneur is able to put more effort into innovation but as a consequence must pay an adverse selection premium. The entrepreneur is constrained.

Denote \( \hat{z} \) the solution to the unconstrained effort choice problem (2.1). If the unconstrained choice respects the bounds of the region without adverse selection, i.e. \( \hat{z} \leq \bar{z} \), then the entrepreneur optimally chooses \( \hat{z} \). If the unconstrained choice violates the bounds of the region without adverse selection, i.e. \( \hat{z} > \bar{z} \), then the optimal choice lies either at the threshold \( \bar{z} \) or within the adverse selection region.

Denote \( z_{as} \) the effort an entrepreneur would choose conditional on staying within the adverse selection region, which satisfies

\[
\mu'(z_{as}) \gamma \pi (1 - \tau_\pi) = N. \tag{3.2}
\]

Suppose the entrepreneur is constrained, then the entrepreneur’s optimal effort choice must be \( z_{as} \). In short, the entrepreneur’s optimal choice solves

\[
\arg \max_{z \in \{\hat{z}, \bar{z}, z_{as}\}} npv(z).
\]

Figure 3.1 describes how the shape of the \( npv \) curve varies across each solution case. The
solid lines represent the $npv$ of the entrepreneur’s project as a function of his choice of research effort. The dashed lines represent, for choices of effort that imply adverse selection, the counterfactual $npv$ of the entrepreneur’s project if the adverse selection problem did not exist.

### 3.3 The Effects of Tax Reform

When entrepreneurs are strategically constrained, the response of research effort to a policy reform is determined by the reform’s impact on the threshold effort $\tilde{z}$. According to lemma 1, the only way to raise research effort in this case is to lower the tax on labor income. Because the entrepreneur is not constrained by his incentives, the effect of a decrease in profit taxes financed by an increase in labor taxes is to lower research effort. Conversely, an effective way to raise research effort when entrepreneurs are strategically constrained is to lower labor income taxes at the expense of higher profit taxes. This leads to the following proposition.

**Proposition 2.** *Lowering the labor income tax rate boosts research effort when entrepreneurs’ optimal effort is just outside the adverse selection region, $z = \tilde{z}$, but are nonetheless constrained, $\tilde{z} < \hat{z}$. As long as the entrepreneur is constrained, this result is independent of whether the labor income tax cut is financed through a higher tax rate on profit or consumption. When the entrepreneur is unconstrained $\hat{z} \geq \tilde{z}$, lowering the labor income tax rate has no effect on research effort if financed through a higher consumption tax, and decreases*
research effort if financed through a higher profit tax.

Proposition 2 has multiple interpretations. First, there is a motive for redistribution from established business owners to workers, since it is beneficial to tax profits to subsidize labor income. When working entrepreneurs and consumers are wealthier, entrepreneurs are able to pledge more networth to their projects and potential imitators must do the same. The cost of imitation rises and the threshold level of research effort pushes outward. The benefit of redistribution stems from the asymmetric information problem.

Thinking further, however, increasing profit taxes cannot be an effective way to increase research effort very much, since eventually entrepreneurs become unconstrained by their relatively high networth and poor incentives, at which point further increases in the profit tax are growth-reducing. On the other hand, taxing consumption to finance simultaneous reductions in the tax rates on profit and labor avoids this limitation. In fact, even without a change in profit taxation, taxing consumption to finance a reduction in the labor income tax relaxes the financial constraint and spurs growth.

This leads to another subtle and important interpretation of the proposition. If governments believe financial constraints hold back entrepreneurial activity, they should restructure their sources of tax revenue. They should rely on consumption rather than income taxation. This result resonates with the literature on fundamental tax reform, which has for some time argued in favor of transitioning from an income-based to a consumption-based tax system. For example, Altig, Auerbach, Kotlikoff, Smetters, and Walliser (2001) argue that for the U.S. economy fundamental tax reform would substantially increase output in the long-run. Their analysis, however, does not take into account the consequences of tax reform for endogenous growth externalities. As they acknowledge, this could be an important source of economic efficiency gains. This paper suggests another reason why taxing consumption may be particularly beneficial, namely that it does not adversely affect the financing constraints of entrepreneurs. At the same time, lowering labor income taxes frees up networth for entrepreneurs to pledge. Because externalities tend to make the rate of technological innovation suboptimal, the benefits to output growth of avoiding tax policies which constrain the financing of innovation is particularly important. Chambers and Lopez (1987) make a related point when studying the effects of tax policy on the decisions of financially constrained farmers. They argue that lowering the income tax allows constrained farmers to accumulate networth faster while a consumption tax does not distort their investment decisions, so that as a net result replacing the income tax with a consumption tax relaxes farmers' financing constraints.

\footnote{Of course, this result is special to the the assumptions of this model. Consumption taxes neither cause tax evasion nor do they interact with labor effort (there is no disutility of labor).}
4 Optimal Policy

A major drawback of policy analysis in the benchmark Schumpeterian growth model is that, because financial markets are perfect, there are few sources of frictions to discipline the government’s optimal tax policy. In particular, the networth of entrepreneurs does not affect their research effort, and hence the government can tax labor income without affecting research effort.

In this section, I explain how adverse selection affects the design of policies able to implement the first-best allocation. I show how restricting the government’s sources of tax revenues leads to the un-implementability of the first-best allocation but not the constrained first-best allocation, and why the government may find it optimal to implement an equilibrium with adverse selection.

4.1 First-Best Allocation

For now, consider the benchmark model and ignore the adverse selection problem. The government behaves as a social planner whose objective is to maximize the expected total consumption across time (and generations) discounted at rate $0 < \beta < 1$. It picks a constant productivity-adjusted research effort across industries. The planner’s objective, normalized for initial average productivity $A_0$,

$$\sum_{t=0}^{\infty} (\beta^g)^t \frac{C_t}{A_0} = \frac{c(z)}{1 - \beta g(z)}.$$

Since productivity-adjusted investment increases with research effort (see appendix A), expression (2.2) implies productivity-adjusted consumption unambiguously decreases with research effort, $c'(z) = -1 - i'(z) < 0$. On the other hand, the growth rate of productivity increases with research effort, and hence so does the denominator of the objective. Let

$$v(z) \equiv \frac{c(z)}{1 - \beta g(z)}.$$

Then, optimal research effort $z^*$ is given by

$$z^* = \arg \max_z v(z),$$

which implies

$$\frac{-c'(z^*)}{\mu'(z^*)} = \frac{\beta (\gamma - 1) c(z^*)}{1 - \beta g(z^*)}. \quad (4.1)$$
As before, denote \( \hat{z}(\tau) \) the entrepreneur’s privately-optimal research effort, and in particular \( \hat{z}^{LF} \) under laissez-faire (i.e. \( \tau = 0 \)). Compare (4.1) with the private research effort equation under laissez-faire,

\[
\frac{1}{\mu'(\hat{z}^{LF})} = \gamma \pi.
\]

As in Aghion and Howitt (1992), there are four effects that determine the disparity between the private and social returns to innovation. First, the government takes into account the intertemporal spillover effect, which is captured by the discount rate \( \beta g \). An entrepreneur only considers the one-period ahead value of innovation, while the government values the entire discounted stream of future benefits. Second, the government measures the effect of innovation on consumption \( c \) rather than profit \( \pi \); this is called the appropriability effect. Third, the government accounts for the business-stealing effect, i.e. an innovation’s destruction of the monopoly generated by the previous innovation, by scaling the consumption gain by \( \gamma - 1 \) rather than \( \gamma \). Fourth, the monopoly distortion effect implies that the monopolist looks at the private cost rather than the social cost of research. The social cost is higher than the private cost, \( -c'(z^*) \geq 1 \) because the entrepreneur ignores the effect of his infinitesimal research choice on aggregate investment demand, and investment demand increases with research effort. The spillover and appropriability effects tend to make laissez-faire research lower than the optimum, while the business-stealing and monopoly distortion effects push research effort up. The net direction depends on the strength of each effect, which are determined by the model parameters: competitiveness of the economy (captured by \( \alpha \)), the size of innovations \( \gamma \), and the government’s discount rate \( \beta \). In this paper, these effects do not play a central role in and of themselves; they motivate a divergence between the social and private returns to technological research.

Implementation

**Definition.** Policy \( \tau^* \) implements the first-best research effort \( z^* \) if

(a) the entrepreneur’s choice of effort equals \( z^* \), and

(b) the policy \( \tau \) satisfies the government budget constraint (2.3).

In order to implement the first-best, the government must tax profits at rate \( \tau^* \), which satisfies

\[
1 = \mu'(z^*) \gamma \pi (1 - \tau^*_\pi).
\]

(4.2)

The government budget constraint requires the tax rates on labor and consumption to balance the budget. But, these adjustments do not impact research effort. So, any feasible combination of taxes on labor and consumption able to finance \( \tau^*_\pi \) implements the optimal policy.
Assumption 3. The first-best allocation \( z^* \) is higher than laissez-faire, but low enough such that the profit subsidy required to implement it can be financed solely through a tax on labor income.

Governments for either political or practical reasons only rely so much on consumption taxes. It is more likely that, were the government to seriously attempt to narrow the gap between the private and social returns to research, the source of revenue would be income taxes. Given assumption 3, the use of the consumption tax is not necessary to implement the first-best allocation. However, although in this benchmark model financing profit subsidies through high labor income taxes is effective, it is less so in the presence of adverse selection, because the contribution of entrepreneurs to their own projects constrains the scale of the projects they may undertake.

4.2 Constrained First-Best Allocation

Now consider the model with adverse selection. The adverse selection problem has no effect on the first-best allocation. It remains true that, if the government was able to, it would want to induce the first-best allocation of the benchmark model, i.e. the first-best level of research effort in an equilibrium free of adverse selection. However, it is possible that in order for the government to implement the first-best level of research effort it would have to allow adverse selection in equilibrium. In that case, because the social cost of research is higher under adverse selection, the first-best level of research effort induces an allocation that is higher than socially optimal. In other words, the optimal implementable allocation (i.e. the second-best allocation) must feature a lower than first-best level of research effort even though the government could implement an equilibrium [with adverse selection] at the first-best level of research effort. I call the optimal allocation among equilibria with adverse selection the constrained first-best allocation, as it is conceptually similar to the first-best allocation, but accounts for the resource loss from the wasteful repetition of research effort.

Suppose consumers always choose to imitate. Imitators generate a negative social return equal to \(- (1 - \theta)\). For every unit of consumption good spent on imitative research, imitators are able to recover a fraction \(\theta\) as a private benefit. The social return to imitation, multiplied by total imitative effort \((N - 1) z\), shows up in aggregate consumption \(c^{as}(z)\)

\[
c^{as}(z) = y - i(z) - [1 + (N - 1)(1 - \theta)] z,
\]
and the government’s welfare function becomes

\[ v^{as}(z) \equiv \frac{c^{as}(z)}{1 - \beta g(z)}. \]

Define the constrained first-best allocation, \( z^{\ast}_{as} \), as the level of research effort that the government would like to implement if it presumes financial markets exhibit adverse selection everywhere, i.e.

\[ z^{\ast}_{as} = \arg \max_{z \geq 0} v^{as}(z). \]

Conditional on inducing an equilibrium with adverse selection, the constrained first-best allocation is the socially-optimal allocation.

**Implementation**

**Definition.** Policy \( \tau^{\ast}_{as} \) implements the constrained first-best research effort \( z^{\ast}_{as} \) with adverse selection if (a) the entrepreneur’s threshold level of research effort is strictly lower than \( z^{\ast}_{as} \), (b) the entrepreneur’s choice of effort equals \( z^{\ast}_{as} \), and (c) the policy \( \tau \) satisfies the government budget constraint (2.3).

Lemma 1 guarantees that subject to a high enough labor income tax rate the entrepreneur chooses a research effort with adverse selection. Specifically, the labor income tax rate must imply that the entrepreneur’s NPV at the threshold effort is strictly lower than the entrepreneur’s NPV at the constrained first-best effort, \( npv(\hat{z}(\tau^{\ast}_{as})) < npv(z^{\ast}_{as}) \). However, because of lemma 1 it is not necessary to derive this boundary condition. There exists some range of labor income tax rates, including the confiscatory rate \( \tau_w = 1 \), which satisfy this requirement.

Conditional on \( npv(\hat{z}(\tau^{\ast}_{as})) < npv(z^{\ast}_{as}) \), the entrepreneur chooses the constrained first-best research effort if the government taxes profit at rate \( \tau^{\ast}_{\pi,as} \), which satisfies

\[ \mu'(z^{\ast}_{as}) \gamma \pi (1 - \tau^{\ast}_{\pi,as}) = N. \] (4.3)

If the first-best allocation in the benchmark allocation can be financed solely through labor income taxes, so can the [lower] constrained first-best allocation in the model of adverse selection. Assumption 3 guarantees that the constrained first-best allocation is implementable independent of any restriction on consumption taxes.
4.3 Implementation without Adverse Selection

Suppose the government wants to target research effort \( z \) while at the same time avoiding adverse selection.

**Definition.** Policy \( \tau \) implements research effort \( z \) free of adverse selection if (a) the entrepreneur’s threshold level of research effort is weakly higher than \( z \), (b) the entrepreneur’s choice of effort equals \( z \), and (c) the policy \( \tau \) satisfies the government budget constraint (2.3).

(a) implies that the labor income tax cannot be too high. When the labor income tax is high, imitation becomes too attractive and the government cannot sustain an equilibrium without adverse selection. To see this, substitute the threshold condition (3.1) into \( \tilde{z}(\tau) \leq z \):

\[
\tau_w \leq 1 - \theta \frac{z}{w}.
\]

The further \( z \) is from pre-tax labor income \( w \), the lower the labor income tax rate must be to avoid imitation. (b) implies the tax on profit must be low enough\(^9\) to encourage the entrepreneur to choose at least \( z \), i.e. according to the research equation (4.2),

\[
\tau_\pi \leq \frac{\mu'(z) \gamma_\pi - 1}{\mu'(z) \gamma_\pi}.
\]

(c) implies the profit, labor, and consumption tax rates must jointly raise enough revenue to pay for themselves,

\[
\pi \tau_\pi + \tau_w L w + \tau_c c = 0.
\]

The extractive power of the consumption tax is key to implementation. Since a high research effort depends upon generous profit subsidies and low labor income tax rates, the balancing of the budget constraint relies on consumption taxes. Thus, I focus on the consumption tax-minimizing policy.

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\(^9\)To be rigorous, one should also take into account that the profit subsidy cannot be too generous, since then entrepreneurs willingly accept the extra costs of adverse selection to raise their scale and exploit the profit subsidy, i.e. the highest possible project NPV within the adverse selection region cannot be higher than the NPV of the project at the first-best effort level outside the adverse selection region, \( npv(z^{as}(\tau)) \leq npv(z^{*}) \). However, the government could always avoid this constraint by setting a tax rate on profit close enough to the upper bound, at which the entrepreneur’s unconstrained choice matches the threshold. At that point, paying an adverse selection premium cannot be privately-optimal.
Lemma 4. The tax rates on labor income, profit, and consumption:

\[
\begin{align*}
\tau_w &= 1 - \theta \frac{z}{w} \quad (4.4) \\
\tau_\pi &= 1 - \frac{1}{\mu'(z) \gamma_\pi} \quad (4.5) \\
\tau_c &= -\frac{1}{c} \left[ \pi \tau_\pi + \tau_w Lw \right] \quad (4.6)
\end{align*}
\]

implement an equilibrium free of adverse selection with the lowest possible tax on consumption. A higher effort level lowers the required tax rates on labor income and profit, and increases the required tax rate on consumption: \(d\tau_w/dz < 0, d\tau_\pi/dz < 0, \) and \(d\tau_c/dz > 0.\)

4.4 Optimal Implementation

Denote \(\tau^*\) the consumption-tax minimizing policy that implements the first-best allocation, implied by setting \(z = z^*\) in equations (4.4)-(4.6). Suppose the government cannot set a consumption tax-rate higher than \(\tau_c\). When \(\tau_c \geq \tau_c^*\), the constraint doesn’t bind and the government implements the first-best. When \(\tau_c < \tau_c^*\), the government must settle for the second-best allocation, which may or may not exhibit adverse selection.

Proposition 5. There exists a threshold tax rate on consumption, \(\tau_c^{min} \leq \tau_c^*\), such that conditional on setting a tax rate on consumption below \(\tau_c^{min}\), the government implements a second-best equilibrium with adverse selection, while conditional on setting a tax rate on consumption above \(\tau_c^{min}\), the government implements a second-best equilibrium free of adverse selection. The second-best equilibrium with adverse selection is equal to the constrained first-best allocation. Let \(z_{min}\) be the research effort of the equilibrium free of adverse selection implied by the tax rate on consumption \(\tau_c^{min}\). A second-best equilibrium free of adverse selection cannot exhibit a research effort below \(z_{min}\). When the consumption tax minimizing policy implies an equilibrium free of adverse selection with research effort below \(z_{min}\), the government chooses to implement the constrained first-best allocation instead.

Figure 4.1 visually describes this result. The level of research effort below which the government would prefer to implement the constrained first-best allocation, \(z_{min}\), is implied by equating the welfare of the constrained first-best allocation with the welfare of an allocation free of adverse selection with research effort \(z_{min}\), i.e. \(v(z_{min}) = v^{as}(z_{as}^*)\). When the highest research effort the government could implement free from adverse selection equals \(z_1 < z_{min}\), avoiding adverse selection implies technological progress is too slow and the constrained first-best allocation is optimal. When the highest research effort the government
could implement free from adverse selection equals $z_2 \geq z_{\text{min}}$, the waste in resources from adverse selection is too high to rationalize implementing the constrained first-best allocation.

To understand why proposition 5 holds, suppose the government optimally implements an equilibrium without adverse selection at a level of research effort below first-best. Given how much consumption is taxed, there is no better possible allocation. Now, suppose the government lowers the tax rate on consumption. A lower tax rate on consumption implies that either the tax on labor or profit (or both) must be higher to satisfy the government’s budget constraint at the same level of research effort. However, an increase in the labor income tax reduces research effort because the entrepreneurs had just enough net worth to choose the original level of research effort and avoid the adverse selection problem. An increase in the profit tax reduces research effort because entrepreneurs had just enough incentives to choose the original level of research effort. Consequently, research effort decreases and the labor and profit tax rates increase to rationalize a lower tax rate on consumption in an implementation free of adverse selection. When the government employs too low a consumption tax, the downward effect on research effort is so strong as to make it worthwhile for the government to allow adverse selection in order to be able to lower the profit tax to encourage more research and raise the income tax to finance the tax break on profit.
5 A Model of Moral Hazard

A model of moral hazard provides another link between entrepreneurial networth and the pursuit of innovation. Moral hazard constrains an entrepreneur’s choice of research effort by limiting the fraction of profits he can commit to pay outsiders if he successfully innovates. A wealthy entrepreneur is less likely to face this problem because he does not depend as much on outside credit.

In what follows, I express all variables in productivity-adjusted terms and drop the time and industry subscripts. In productivity-adjusted terms, the problem is invariant across entrepreneurs because I assume that all entrepreneurs equally limited in their ability to share profits with outside creditors.

5.1 Entrepreneurial Research

Suppose the entrepreneur cannot commit to pay back creditors when funding research if he expects to receive less than a fraction $\varphi$ of after-tax profits\(^{10}\). If $\varphi$ is high enough, the entrepreneur cannot borrow enough funds to match his unconstrained privately optimal research choice.\(^ {11}\)

The entrepreneur’s problem is to maximize

$$npv(z|\tau) \equiv \mu(z) \gamma (1 - \tau_e) \pi - z$$

subject to an incentive compatibility constraint,

$$\mu(z)(1 - \tau_e) \gamma \pi - d \geq \mu(z) \gamma \pi \varphi (1 - \tau_e)$$

where $d$ is the amount borrowed by the entrepreneur.

As in the adverse selection model, I assume the entrepreneur’s unconstrained choice of project size $\hat{z}$ is larger than his after-tax wage income $(1 - \tau_w)w$. For the remainder of the analysis, I also assume that $\varphi$ is high enough to ensure the IC constraint binds and so the entrepreneur is unable to choose $\hat{z}$. When the IC constraint binds, contributing more networth to the project allows the entrepreneur to increase the project size given some level of outside financing $d$. As a result, the entrepreneur contributes his entire after-tax labor

\(^{10}\)For a behavioral derivation of a constraint of this type, see Hart and Moore (1994)

\(^ {11}\)The literature (Hall and Lerner (2010)) finds that debt financing is not an important source of capital for innovation. This model does not address the difference between equity and debt because of the simple binomial outcome of innovation. However, this is an interesting and controversial issue that merits further attention.
income, 12 and total project size equals $z = (1 - \tau_w) w + d$. The entrepreneur chooses the highest effort $\bar{z}$ that makes the IC constraint bind.

$$\bar{z} = \mu(z) \gamma (1 - \varphi) [1 - \tau_\pi] \pi + (1 - \tau_w) w. \quad (5.1)$$

As $\varphi$ rises, $\bar{z}$ falls until $\varphi \to 1$ and $\bar{z} \to w$. In the limit, the entrepreneur is unable to borrow from outsiders at all. 13

5.2 The Effects of Tax Reform

In the model of adverse selection, movements in research effort in response to tax reforms were driven by the effect of the reform on the labor income tax (see lemma 1). When entrepreneurs face moral hazard, movements in research effort are the result of the net effects on the IC constraint of changes in the labor income and profit tax rates. The impact on the IC constraint of a change in the profit tax rate depends on the aggregate rate of innovation, the pledge-ability of taxes (or subsidies) to outside investors, and the severity of the moral hazard problem.

**Proposition 6.** Assume the tax rate on consumption is positive. Holding fixed the tax on profit, a small reform that increases the consumption tax rate lowers the labor income tax rate and boosts research effort when entrepreneurs are constrained by the moral hazard problem. Holding fixed the tax on consumption, a small reform that increases the tax on profit lowers the labor income tax rate and boosts research effort when entrepreneurs are constrained by the moral hazard problem and either (1) the entrepreneur’s ability to pledge after-tax profits is sufficiently poor, (2) the aggregate rate of innovation is sufficiently low, or (3) entrepreneurs are a large enough part of the labor force.

The model with moral hazard provides a rationale for redistributive policies under some circumstances. A higher tax on profit punishes entrepreneurs for their success, and this would be decisively bad for an unconstrained entrepreneur because then he would have less of an incentive to pursue research. However, a constrained entrepreneur may benefit more from a boost to networth than he is hurt by the loss in incentives or the loss in future pledge-able cash flows. In particular, when the moral hazard problem (applicable to tax-related cash flows) is severe the loss in future pledge-able cash flows is relatively harmless because the entrepreneur is so imperfectly able to pledge future cash flows.

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12 If the IC constraint does not bind, the entrepreneur is indifferent between inside and outside sources of financing, and for parsimony I assume that he contributes all of his income anyway.

13 The expression for the minimum $\varphi$ necessary to constrain the entrepreneur is implied by the IC constraint at equality when the variables equal the unconstrained entrepreneur’s choices.
6 Conclusion

This paper analyzes the design of optimal policy and the effects of policy reforms in a model of adverse selection in the financing of innovation. It accomplishes this task in a simple and straightforward way. Of course, the paper’s simplicity imposes limitations. This paper does not derive optimal policy as the solution to a mechanism design problem, nor even does it consider convex taxation schedules.

The model’s industrial organization is monopolistic. This assumption rules out studying the effects of policies when there are heterogeneously constrained firms competing with each other for market share, a process which naturally should play an important role in understanding the implications of policy for economic growth. Furthermore, the model is carefully constructed so that the choices across firms in different industries are identical in productivity-adjusted terms. Consequently, it cannot address how differences in financial constraints affects growth across industries.

Finally, the absence of a politico-economic structure that endogenizes the process through which government is motivated to pursue policy and how it finances policy reforms is a serious omission of this paper. An environment where both the origins and consequences of policy reforms and long-run policy design had a common root in a political process would allow us to understand when government policy would fail to be optimal, even if we understood how policy could be reformed.
References


A Complete Description of the Benchmark Model

This appendix section describes aspects of the benchmark model omitted from the main body of the paper.

A.1 Consumption Good Production

The production of the consumption good is perfectly competitive and requires a mixture of industry-specific labor $L_{it}$ and intermediate goods $X_{it}$ according to

$$Y_t \equiv \int_0^1 Y_{it} di,$$

$$Y_{it} \equiv (A_{it}L_{it})^{1-\alpha} X_{it}^\alpha, \quad 0 < \alpha < 1$$

Consumption good producers maximize profit taking as given the intermediate good prices $P_{it}$ and wages $W_{it}$

$$\max_{x_{it},L_{it}} Y_t - \int_0^1 (P_{it}X_{it} + W_{it}L_{it}) di,$$

which implies equilibrium expressions for the industry-specific wage and an inverse demand curve for intermediate goods

$$W_{it}L_{it} = (1 - \alpha) Y_{it}$$

$$P_{it} = \alpha \left( \frac{A_{it}L_{it}}{X_{it}} \right)^{1-\alpha}.$$  

Because the technology is linear and the sector is competitive, neither is there an equilibrium benefit or cost to becoming a consumption good producer nor does the distribution of production across producers matter. For these reasons, it is not necessary to specify the owners of these firms. And, in the equilibrium equations I can treat $X_{it}$ and $L_{it}$ as the sector-wide demand for these factors. Furthermore, $L_{it} = L$ since the supply of industry-specific labor is inelastic.

The direct interpretation of technology $A_{it}$ in the model is the consumption good producer’s industry-specific labor productivity. However, it may be more fruitful to think about $A_{it}$ as a general measure of the technological advancement of an industry. The key feature of technological advancement in the model is that innovations in a particular industry increase the relative demand for the good produced by that industry.
A.2 Intermediate Good Production

An investment of $I_{it}$ consumption goods at $t$ yields $X_{i,t+1} = I_{it}$ intermediate goods at $t + 1$. The interest rate is $1 + r_{t+1}$. The intermediate good is produced by a monopolist, whom understands that if he produces $X_{i,t+1}$ goods of quality $A_{i,t+1}$, the goods sell at price $P_{it} = \alpha \left( \frac{A_{it}L_{it}}{X_{it}} \right)^{1-\alpha}$. At the time of production, the good’s quality $A_{i,t+1}$ is pre-determined. The monopolist chooses $I_{it}$ to maximize discounted profit

$$\Pi_{i,t+1} = \frac{P_{i,t+1}X_{i,t+1} - (1 + r_{t+1})I_{it}}{1 + r_{t+1}} = \left( \frac{P_{i,t+1}}{1 + r_{t+1}} - 1 \right) I_{it},$$

which in equilibrium implies (after substitution of the inverse demand curve) the monopolist chooses price

$$\frac{P_{i,t+1}}{1 + r_{t+1}} = \frac{1}{\alpha},$$

and investment and profit are linear functions of productivity $A_{i,t+1}$,

$$I_{it} = \left( \frac{\alpha^2}{1 + r_{t+1}} \right)^{1/\alpha} A_{i,t+1}L_{it},$$

$$\Pi_{i,t+1} = (1 - \alpha) \alpha^{\frac{1}{1-\alpha}} \left( 1 + r_{t+1} \right)^{\frac{1}{1-\alpha}} A_{i,t+1}L_{it}.$$

The contribution of each industry toward the production of the consumption good is driven by the scale of production and technological change. The marginal contribution of each industry at $t + 1$ is

$$Y_{i,t+1} = (A_{i,t+1}L_{it})^{1-\alpha} (I_{it})^{\alpha} = \frac{1 + r_{t+1}}{\alpha^2} I_{it} = \frac{1 + r_{t+1}}{\alpha (1 - \alpha)} \Pi_{i,t+1}.$$

A.3 Aggregate Variables

The linearity of the industry-specific equations and the convenience of the notation adopted make aggregation simple. Total investment and output are

$$I_t = \frac{\alpha}{1 - \alpha} \Pi_{t+1},$$

$$Y_{t+1} = \frac{1 + r_{t+1}}{\alpha (1 - \alpha)} \Pi_{t+1}.$$

\[\text{For ease of exposition, I will phrase as many variables as possible in terms of the monopolist’s profit. For now, note that } I_{it} = \frac{1}{\alpha^{1/\alpha}} \Pi_{i,t+1}.\]
The total wage bill obeys

\[ W_t L = (1 - \alpha) Y_t. \]

Out of the wage bill, only \((1 - \tau_w) W_t L\) remains as after-tax disposable income of young agents. Other than however much they invest in research and intermediate good production, the young spend their disposable income on consumption. Accounting for the consumption tax, the young consume \(\frac{(1 - \tau_w) W_t L - Z_t - I_t}{1 + \tau_c}\). Aggregate consumption equals output minus the investment of the young in research and intermediate good production. When \(r_{t+1} > 0\), the young invest their entire disposable income. Otherwise, when \(r_{t+1} = 0\) young agents are indifferent between consuming and saving. More succinctly, the equilibrium interest rate \(r_{t+1}\) clears the market for consumption goods if

\[
\left( \frac{(1 - \tau_w) W_t L - Z_t - I_t}{1 + \tau_c} \right) r_{t+1} = 0,
\]

where \(r_{t+1} \geq 0\). In this paper, I only considered parametrizations that implied the equilibrium interest rate equals zero, \(r_{t+1} = 0\).

It is straightforward to reformulate these aggregate variables in productivity-adjusted terms.\(^{15}\)

### A.4 Discussion of Assumptions

The model has a few assumptions that deserve discussion, namely (1) technology enters as a variable in the production of consumption goods rather than intermediate goods, (2) labor is industry-specific yet is not an input into intermediate good production, and (3) there is no competition in the pursuit of technological research, and (4) industries which have not recently experienced an innovation continue to be monopolized.

Most models of imperfection competition assume that a consumption good is produced using a continuum of imperfectly substitutable intermediate goods. Just as in this model, the consumption good producers are perfectly competitive, while the intermediate good producers are monopolists. The inverse demand curve of the monopolist is implied by the first-order condition of consumption good producers. However, labor is not usually an input in the consumption good production function. However, by modeling innovations as labor productivity-augmenting changes in the consumption good production function, the optimal investment decision of the monopolist becomes linear in technology. The linearity of the model substantially simplifies the aggregate and dynamic properties of the economy. For a

\(^{15}\)For example, the wage bill \(w_t L = (1 - \alpha) y_t\), output \(y_{t+1} = \frac{1}{\alpha (1 - \alpha)} (1 + r_{t+1}) \pi_{t+1}\), and investment \(i_t = \frac{\alpha}{1 - \alpha} g_{t+1} \pi_{t+1}\).
textbook treatment of this technique, see Aghion and Howitt (2009).

The discussion above explains why labor should appear in the consumption good production function, but it does not explain why labor should be industry-specific. This refinement is special to my model, and its purpose is to yield a tractable solution even when there exist financial market imperfections, as should be clear later. In a model with financial market imperfections, entrepreneurial networth is an important determinant of investment in technological research. In a common labor market wherein all entrepreneurs are born with equivalent labor endowments, entrepreneurs earn equivalent labor incomes. On the other hand, since innovation profits are linear in productivity and an innovating entrepreneur has monopoly power, the benefit to research is larger for entrepreneurs in high versus low productivity industries. Thus, entrepreneurs with low networth in high productivity industries should be more constrained than entrepreneurs with high networth in low productivity industries. Since networth is equivalent to labor income in the model, and labor income is equivalent across entrepreneurs in a common labor market, indeed entrepreneurs would be heterogeneously affected by financial market imperfections if I assumed a common labor market. To avoid this channel, which is not of first-order importance to the themes of this paper and hence not worth the added complexity, I assume that the labor market for each industry is fragmented. In this way, networth scales with the gains from research in any given industry. One last assumption is crucial to ensure that both the financial market imperfections symmetrically affect entrepreneurs and that the model has nice convergence properties: the contribution of some fixed research effort to the probability of innovation decreases inverse-linearly with the productivity of the entrepreneur’s industry. Otherwise, an entrepreneur whom did not face sufficiently steep increasing costs to research would expand his research effort until his probability of innovation approached one (at infinity), whereas he would invest a negligible share of networth on research, implying that the financial market imperfections would have no effect in steady state. If the increase in research costs were too steep, the entrepreneur’s desired research effort would approach zero, and there would not exist a [positive] balanced growth path.

If multiple entrepreneurs could compete, or consumers were able to enter the entrepreneurial sector to compete, in the pursuit of technological research, several interesting but distracting issues would arise. I could study how financial market imperfections affect the equilibrium number of participants in the market for innovations and the division of profits across the possibly multiple entrepreneurs that innovate simultaneously within a given industry. Further, I could study the impact of research replication on the gap between the social and private returns to research and policies that address the inefficiency. Beyond this, there are many more issues to think carefully about, and which are quite interesting. However, like
Aghion and Howitt (2009), I assume that only one research-able entrepreneur exists at any
time within an industry precisely to ignore all of these issues. Throughout the paper, it will
be clear that this assumption does not interfere with the paper’s contributions, although
admittedly, relaxing the assumption would yield a richer modeling environment and expand
the breadth of the paper’s contributions.

The hallmark of the Schumpeterian growth literature is to view the rents from innovation
as consequences of the monopolistic environments that innovations create. Thus, it may seem
strange than in this model, as in Aghion and Howitt (2009), even industries which have not
recently experienced innovations are monopolized. The reason for this assumption is partly
simplicity. Suppose instead that any industry wherein an innovation has not recently oc-
curred enjoys perfect competition. The level of production relative to productivity would rise
in those industries absent the monopolistic distortion. Thus, the functional form of invest-
ment would not be identical across industries and the expression for aggregate investment
would be more complicated. The gap between the social and private returns to research
would slightly diminish since innovations rupture an industry’s competitive equilibrium in
favor of a [distorted] monopolistic environment. Although such an environment would imply
some slight variations on the contributions of this paper, they are not sufficiently important
to justify a more complex model.


B Proofs

Lemma 1. Holding fixed the model parameters, an increase in the tax rate on labor income $\tau_w$ lowers the threshold level of research effort $\tilde{z}$. In other words, the interval of research effort choices $[0, \tilde{z}]$ over which the entrepreneur would not pay an adverse selection premium narrows. As the tax becomes confiscatory, $\tau_w \to 1$, the entrepreneur is forced to finance the project with adverse selection, since $\tilde{z} \to 0$.

Proof. The statement follows immediately from equation (3.1).

Proposition 2. Lowering the labor income tax rate boosts research effort when entrepreneurs’ optimal effort is just outside the adverse selection region, $z = \tilde{z}$, but are nonetheless constrained, $\tilde{z} < \tilde{z}$. As long as the entrepreneur is constrained, this result is independent of whether the labor income tax cut is financed through a higher tax rate on profit or consumption. When the entrepreneur is unconstrained $\tilde{z} \geq \tilde{z}$, lowering the labor income tax rate has no effect on research effort if financed through a higher consumption tax, and decreases research effort if financed through a higher profit tax.

Proof. Consider small increases in the tax rates on profit, $d\tau_\pi$, and consumption, $d\tau_c$. The total derivative of the government budget constraint (2.3) is $wL \cdot d\tau_w + \pi \cdot d\tau_\pi + \tau_c \cdot dc + c \cdot d\tau_c = 0$. Because the entrepreneur is strategically constrained and the reform is small, research effort obeys equation (3.1). Hence, the effect of the change in the labor income tax on research effort is $dz = -\frac{w}{\pi} d\tau_w$. The expression for aggregate consumption (2.2) implies the effect of the change in research effort on consumption is $dc = -[\pi'(z) + 1] dz$. Putting all this together, the budget constraint implies

$$d\tau_w = -\frac{\pi/w}{L + [\pi'(z) + 1]} d\tau_\pi - \frac{c/w}{L + [\pi'(z) + 1]} d\tau_c.$$

So, either small increases in the tax rates on profit or consumption lower the labor income tax. In turn, $dz = -\frac{w}{\pi} d\tau_w$ implies that a fall in the labor income tax causes research effort to increase. When the entrepreneur is unconstrained, there is no marginal relationship between networth and research effort. Consequently, lowering the labor income tax has no effect on research effort. If lowering labor income tax is financed by raising the tax on consumption, which also does not affect research effort, the reform has no net effect on research effort. If lowering labor income tax is financed by raising the tax on profit, research effort decreases because there is a negative relationship between the tax on profit and research effort. To see the negative relationship between tax on profit and research effort differentiate the research
equation (2.1). Then,
\[ dz = \gamma \pi \left( \frac{\mu'}{\mu''} \right)^2 d\tau_\pi. \]
Because the research function \( \mu(z) \) is concave, \( \gamma \pi \left( \frac{\mu'}{\mu''} \right)^2 < 0 \).

**Lemma 4.** The tax rates on labor income, profit, and consumption:
\[
\begin{align*}
\tau_w &= 1 - \frac{\theta}{w} \\
\tau_\pi &= 1 - \frac{1}{\mu'(z) \gamma \pi} \\
\tau_c &= -\frac{1}{c} \left[ \pi \tau_\pi + \tau_w Lw \right].
\end{align*}
\]
implement an equilibrium free of adverse selection with the lowest possible tax on consumption. A higher effort level lowers the required tax rates on labor income and profit, and increases the required tax rate on consumption: \( d\tau_w/dz < 0 \), \( d\tau_\pi/dz < 0 \) and \( d\tau_c/dz > 0 \).

**Proof.** The consumption tax-minimizing policy is that which sets a labor income tax just low enough that the entrepreneur is able to finance the first-best level of research effort and a profit tax just low enough that he has the incentive to do so. The consumption tax follows from the government’s budget constraint. \( d\tau_w/dz = -\frac{\theta}{w} < 0 \), \( d\tau_\pi/dz = \frac{1}{\mu''(z) \gamma \pi} < 0 \), since \( \mu(z) \) is concave. \( d\tau_c/dz = \frac{1}{c} \tau_c^d \frac{dc}{dz} - \frac{1}{c} \left[ \pi \tau_\pi + \tau_w Lw \right] < 0 \), since the other tax rates have negative derivatives and productivity-adjusted aggregate consumption decreases with research effort, \( dc/dz < 0 \), as is clear from the discussion in section 4.1.

**Proposition 5.** There exists a threshold tax rate on consumption, \( \tau_c^{min} \leq \tau_c^* \), such that conditional on setting a tax rate on consumption below \( \tau_c^{min} \), the government implements a second-best equilibrium with adverse selection, while conditional on setting a tax rate on consumption above \( \tau_c^{min} \), the government implements a second-best equilibrium free of adverse selection. The second-best equilibrium with adverse selection is equal to the constrained first-best allocation. Let \( z_{min} \) be the research effort of the equilibrium free of adverse selection implied by the tax rate on consumption \( \tau_c^{min} \). A second-best equilibrium free of adverse selection cannot exhibit a research effort below \( z_{min} \). When the consumption tax minimizing policy implies an equilibrium free of adverse selection with research effort below \( z_{min} \), the government chooses to implement the constrained first-best allocation instead.

**Proof.** Let \( z_{min} \) denote the research effort for which the welfare of an equilibrium without adverse selection is equivalent to that of an equilibrium with adverse selection at the constrained first-best level of research effort \( z_{as}^* \). The government would prefer to implement
the constrained first-best allocation when free of adverse selection it would only be able to implement a research effort lower than \( z_{\text{min}} \). The value for \( z_{\text{min}} \) is given by the solution to

\[
v(z_{\text{min}}) = v^{as}(z^{as}).
\]

Because in the equilibrium with adverse selection the cost of research is higher, it must be that \( z_{\text{min}} < z^{as} \).

The variable \( z_{\text{min}} \) dictates how severe the limitations on implementing a high research effort without adverse selection have to be in order for the government to prefer to implement an equilibrium with adverse selection. Since the constrained first-best allocation is the socially optimal allocation with adverse selection, and the constrained first-best allocation is implementable with any non-negative tax rate on consumption, then the government will uniquely implement the constrained first-best allocation among candidate allocations with adverse selection.

When the government is able to implement a research effort without adverse selection and higher than \( z_{\text{min}} \), the constrained first-best allocation cannot be socially optimal. However, when the highest research effort implementable without adverse selection falls short of \( z_{\text{min}} \), the constrained first-best allocation is socially optimal. Let \( \tau^{\text{min}}_c \) be the lowest consumption tax that implements research effort \( z_{\text{min}} \) without adverse selection (see lemma 4). If the government cannot tax consumption at the rate \( \tau^{\text{min}}_c \) or higher, then it can only implement an equilibrium free of adverse selection with research effort lower than \( z_{\text{min}} \).

\[ \square \]

**Proposition 6.** Assume the tax rate on consumption is positive. Holding fixed the tax on profit, a small reform that increases the consumption tax rate lowers the labor income tax rate and boosts research effort when entrepreneurs are constrained by the moral hazard problem. Holding fixed the tax on consumption, a small reform that increases the tax on profit lowers the labor income tax rate and boosts research effort when entrepreneurs are constrained by the moral hazard problem and either (1) the entrepreneur’s ability to pledge after-tax profits is sufficiently poor, (2) the aggregate rate of innovation is sufficiently low, or (3) entrepreneurs are a large enough part of the labor force.

**Proof.** Consider small increases in the tax rates on profit, \( d\tau_\pi \), and consumption, \( d\tau_c \). Because entrepreneurs are constrained, research effort is given by 5.1. The effect of a tax change on research effort is

\[
[1 - \mu'(\bar{z})\gamma (1 - \varphi)(1 - \tau_\pi)\pi] \, d\bar{z} = -w \cdot d\tau_w - \mu(\bar{z})\gamma (1 - \varphi)(1 - \pi) \cdot d\tau_\pi
\]
Differentiating the government budget constraint (2.3) implies relationships between changes in the tax rates on labor, profit, and consumption,

\[ wL \cdot d\tau_w + \pi \cdot d\tau_\pi + \tau_c \cdot dc + c \cdot d\tau_c = 0. \]

Using the differentiated budget constraint to substitute out the labor income tax from the differentiated IC constraint yields

\[ [1 - \mu'(\bar{z}) \gamma (1 - \varphi) (1 - \tau_\pi) \pi] d\bar{z} = \]

\[ \pi \left[ \frac{1}{L} - \mu(\bar{z}) \gamma (1 - \varphi) \right] d\tau_\pi + \frac{1}{L} (\tau_c \cdot dc + c \cdot d\tau_c). \]

The expression for aggregate consumption (2.2) implies the effect of the change in research effort on consumption is \( dc = -[i'(z) + 1]dz \). An increase in research effort lowers consumption, which in turn lowers tax revenues from consumption since \( \tau_c > 0 \) and so dampens the effect of tax changes on research effort. Taking this effect into account implies

\[ \left( 1 - \mu'(\bar{z}) \gamma (1 - \varphi) (1 - \tau_\pi) \pi + \tau_c \frac{1}{L} [i'(\bar{z}) + 1] \right) d\bar{z} = \]

\[ \pi \left[ \frac{1}{L} - \mu(\bar{z}) \gamma (1 - \varphi) \right] d\tau_\pi + c \cdot d\tau_c. \]

The term in front of \( d\bar{z} \) is positive because both \( 1 - \mu'(\bar{z}) \gamma (1 - \varphi) (1 - \tau_\pi) \pi > 0 \) and \( \tau_c \frac{1}{L} [i'(\bar{z}) + 1] > 0 \). The latter expression is positive because of the assumption that the tax rate on consumption is positive. The first expression is positive because of how the maximum effort \( \bar{z} \) is defined. \( \bar{z} \) is the maximum research effort that satisfies the IC constraint, so the derivative of the IC constraint at \( \bar{z} \) must be negative, since otherwise the entrepreneur could relax the constraint by choosing a higher effort. That is,

\[ 1 - \mu'(\bar{z}) \gamma (1 - \varphi) (1 - \tau_\pi) \pi > 0. \]

The sign of the partial derivative of \( \bar{z} \) with respect to \( \tau_c \),

\[ L \cdot \frac{\partial \bar{z}}{\partial \tau_c} \bigg|_{\tau_c} = \frac{c}{1 - \mu'(\bar{z}) \gamma (1 - \varphi) (1 - \tau_\pi) \pi + \tau_c \frac{1}{L} [i'(\bar{z}) + 1]} \]

is positive since consumption is positive. This implies that raising the consumption tax holding the profit tax fixed relaxes the entrepreneur’s IC constraint and boosts research
effort. The sign of the partial derivative of $\bar{z}$ with respect to $\tau_{\pi}$

$$
\frac{1}{\pi} \cdot \frac{\partial \bar{z}}{\partial \tau_{\pi}} \bigg|_{\tau_c} = \frac{\frac{1}{L} - \mu(\bar{z}) \gamma (1 - \varphi)}{1 - \mu'(\bar{z}) \gamma (1 - \varphi) (1 - \tau_{\pi}) \pi + \tau_c \frac{1}{L} \left[ \mu'(\bar{z}) + 1 \right]}
$$

is positive when (1) the entrepreneur’s ability to pledge after-tax profits is sufficiently poor, as implied by a high $\varphi$, (2) the aggregate rate of innovation $\mu(\bar{z})$ is sufficiently low, or (3) entrepreneurs are a large enough part of the labor force, i.e. $L$ is small.