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Innovation, Human Capital, and Taxation: Evidence from a Structural Model of the Canadian Economy

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ABSTRACT: Canada's innovation performance has been strong but shows limited upward momentum despite generous research and development (R&D) subsidies. This paper develops an endogenous innovation, multi-sector, heterogeneous-agent model calibrated to the Canadian economy to evaluate fiscal policies that promote innovation and growth. The impact of R&D subsidies depends critically on the supply of high-skilled labor. When the supply of scientists is inelastic, subsidies raise research wages, crowd out private R&D, and can reduce long-run growth. When labor supply is more elastic, subsidies generate substantial gains in innovation and output. The analysis also compares alternative policy instruments. Investment tax reductions and education spending foster innovation through capital deepening and an expanded supply of highskilled labor, delivering more robust gains when talent constraints bind, while personal income tax changes have more limited effects. R&D subsidies also increase inequality by disproportionately benefiting high-skilled workers, although these effects are mitigated when labor supply responds. Overall, effective innovation policy requires combining R&D incentives with policies that expand human capital and reduce distortions to investment.

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Innovation, Human Capital, and Taxation:

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1 Introduction

Innovation is a central driver of long-term economic growth and productivity. Canada provides a particularly relevant case study:¹ while it ranks highly in international measures of innovation inputs—such as scientific output and public support for research—its innovation outcomes and productivity growth have shown limited upward momentum over the past decade. At the same time, Canada offers among the most generous research and development (R&D) tax incentives among advanced economies, yet business R&D investment remains modest relative to leading innovators.²

This apparent disconnect raises a key policy question: to what extent can additional fiscal incentives effectively stimulate innovation when underlying constraints may lie elsewhere? Evidence points to structural bottlenecks in the innovation ecosystem, including shortages of high-skilled labor, uneven technology diffusion, and limited capacity to scale new ideas into commercially viable products. Among these, constraints on the supply of high-skilled workers—particularly scientists and engineers—have emerged as a central concern (e.g., Akcigit et al., 2020; Van Reenen, 2021). This paper places this constraint at the center of innovation policy. It shows that the effectiveness of R&D subsidies is fundamentally shaped by general equilibrium adjustments in the supply of research talent, making the scientist labor bottleneck a key determinant of both growth and distributional outcomes.

This paper argues that the effectiveness of R&D subsidies critically depends on the availability of high-skilled labor. When the supply of scientists is inelastic, expanding fiscal incentives generates general equilibrium effects that offset their intended impact. Higher subsidies increase the demand for research labor, raise its relative price, and reallocate talent across sectors, crowding out private R&D investment and dampening long-term growth. Conversely, when the supply of high-skilled workers is sufficiently elastic, the same policies can significantly enhance innovation and productivity.

To study these mechanisms, the paper develops an endogenous innovation, multi-sector, heterogeneous-agent model calibrated to the Canadian economy. Firms invest in R&D to accumulate sector-specific technologies, high-skilled workers choose between production and research occupations, and fiscal policy affects both innovation incentives and labor supply decisions. This framework allows us to evaluate how R&D subsidies interact with labor market constraints, sectoral composition, and general equilibrium price adjustments.

¹The analysis in this paper is closely related to policy discussions in the 2025 IMF Article IV consultation for Canada.

²Supporting cross-country evidence is presented in Appendix C.

The analysis focuses on long-run steady-state comparisons across policy regimes. As such, the results should be interpreted as characterizing the persistent effects of policy changes after full adjustment of prices, allocations, and occupational choices.

The quantitative analysis shows that the growth effects of R&D subsidies are highly non-linear and depend on the elasticity of high-skilled labor supply. When the supply of scientists is relatively inelastic, subsidies generate limited gains and may reduce long-run growth. In contrast, policies that expand the pool of high-skilled workers—such as increased education spending—substantially amplify the effectiveness of fiscal incentives and lead to stronger and more sustained growth. Investment tax reductions also promote innovation through capital deepening, while personal income tax changes have more limited effects.

The paper also highlights important distributional trade-offs. R&D subsidies tend to increase inequality by disproportionately benefiting high-income individuals employed in research occupations. These effects are mitigated when labor supply is more elastic, but remain quantitatively relevant for policy design.

This paper contributes to three strands of the literature by placing endogenous scientist supply at the center of innovation policy in a general equilibrium framework with distributional implications. First, it contributes to research on R&D tax incentives and subsidies by highlighting the role of endogenous labor supply and occupational choice in shaping policy effectiveness. Second, it contributes to the literature on human capital and endogenous growth by quantifying how constraints on research talent affect innovation dynamics in a general equilibrium setting. Third, it contributes to work on fiscal policy design in small open economies by providing a framework to evaluate the interaction between taxation, sectoral structure, and innovation.

The remainder of the paper is organized as follows. Section II presents the model. Section III discusses the calibration. Section IV reports the main results. Section V concludes.

2 Model

This section presents a quantitative general equilibrium model designed to evaluate how fiscal policy affects innovation and long-term growth in the presence of labor market constraints. The framework is tailored to capture the interaction between R&D incentives and the supply of high-skilled labor.

Relative to standard models of endogenous innovation, the framework incorporates three key departures.

First, technology enters production as an input alongside capital and labor, rather than

as a purely multiplicative productivity term. As a result, changes in technology affect production through input demand and substitution patterns.

Second, innovation is not summarized solely by the stock of technology. Instead, it depends jointly on the stock of technologies, the level of research capital, and the productivity of scientists. This allows policy to affect different margins of innovation separately.

Third, the model combines endogenous innovation with household heterogeneity and occupational choice. High-skilled workers decide whether to work in production or research, making the supply of scientists endogenous and responsive to policy-induced wage changes.

These features imply that changes in R&D incentives do not necessarily translate one-for-one into changes in the equilibrium stock of technology, as the effectiveness of technology depends on the allocation of complementary inputs.

The economy is a small open economy with three production sectors: tradable goods (T1), low-technology services (N1), and high-technology services (N2). Firms invest in research and development (R&D) to accumulate sector-specific technologies that enhance production and generate spillovers across sectors.

Households are heterogeneous in both wealth and human capital. They are divided into three groups according to their level of human capital—low (U), medium (X), and high (S)—and are subject to idiosyncratic productivity shocks. While low- and medium-skilled households supply labor only to production activities, high-skilled households choose how to allocate their time between production and R&D, giving rise to an endogenous supply of research labor.

Time is discrete. Decisions about capital and technology taken at time t affect future production and innovation outcomes. Fiscal policy operates through two main channels: by altering firms' incentives to invest in innovation and by influencing households' labor supply and occupational choices, particularly the allocation of high-skilled workers to research.

We begin by describing the household problem, followed by firms' production and innovation decisions, and finally the role of government policy and the definition of equilibrium.

2.1 Households

Households differ in wealth, human capital, and exposure to idiosyncratic risk, and make consumption, savings, and labor supply decisions. A key feature of the model is that high-skilled households choose whether to work in production or research activities, determining the endogenous supply of scientists.

2.1.1 Households' Labor Productivity Shocks

Individual productivity follows a stochastic process that differs across skill groups. For high-skilled workers, productivity also depends on occupational choice, with research activities involving higher idiosyncratic risk.

Specifically, for households with high-human-capital (S), the underlying productivity component ε^{iS} follows an AR(1) process:

$$\varepsilon_t^{iS} = \rho^S \varepsilon_{t-1}^{iS} + \epsilon_t^{iS},$$

where $\epsilon_t^{iS} \sim \mathcal{N}(0, \sigma^{\epsilon, S})$.

Actual labor productivity for high-human-capital households depends on their occupational choice. When working in production, productivity coincides with the underlying shock:

$$\varepsilon_t^{iS^P} = \varepsilon_t^{iS}.$$

When working in R&D, labor productivity incorporates an additional occupation-specific component, implying higher risk:

$$\varepsilon_t^{iS^Q} = \rho^S \varepsilon_{t-1}^{iS} + \epsilon_t^{iS^Q},$$

where $\epsilon_t^{iS^Q} \sim \mathcal{N}(0, \sigma^{\epsilon^Q})$, with

$$\sigma^{\epsilon^Q} = \sigma^{\epsilon^S} + \bar{l}, \quad \bar{l} > 0.$$

Therefore, labor productivity risk is higher in R&D than in production.

Labor productivity shocks for households with low ($j = U$) and medium ($j = X$) human capital follow an analogous process but apply only to production activities.

2.1.2 Households' optimization problem

A household of type S solves:

$$\max_{c_t^{iS}, l_t^{iS}, a_{t+1}^{iS}} E_0 \sum_{t=0}^{\infty} \beta^t u(c_t^{iS}, l_t^{iS})$$

subject to:

$$(1 + \tau_{c,t}^{T1})c_t^{iS,T1} + (1 + \tau_{c,t}^F)p_t^F c_t^{iS,F} + (1 + \tau_{c,t}^{N1})p_t^{N1} c_t^{iS,N1} + (1 + \tau_{c,t}^{N2})p_t^{N2} c_t^{iS,N2} + a_{t+1}^{iS} =$$

$$(1 - \tau_t^w) \left[w_t^{SP} l_t^{iSP} \varepsilon_t^{iSP} + w_t^{SQ} l_t^{iSQ} \varepsilon_t^{iSQ} \right] + (1 + r_t) a_t^{iS} - \mathbb{T}(\cdot) + Trans_t^{iS}.$$

where $c_t^{e,ij}$, p_t^e , and $\tau_{c,t}^e$ denote consumption, relative prices, and consumption taxes for goods $e \in \{T1, F, N1, N2\}$, respectively, with $p^{T1} = 1$ since domestically produced tradable goods are the numeraire. Assets a_t^{ij} denote financial wealth held at the beginning of period t , and r_t is the real interest rate. l_t^{iSP} and l_t^{iSQ} denote hours supplied to production and R&D activities, respectively, and w_t^{SP} and w_t^{SQ} are the corresponding wages, τ_t^w is the payroll tax. The function $\mathbb{T}(\cdot)$ denotes income taxes, which depend on both labor and asset income, and $Trans_t^{ij}$ denotes government transfers.

Working in R&D requires different abilities than production, implying imperfect substitutability between occupations. Consistently, total labor supplied by type- S households is given by:

$$l_t^{iS} = \left[(\kappa^{iS})^{\frac{1}{\theta^{iS}}} (l_t^{iSP})^{\frac{\theta^{iS}-1}{\theta^{iS}}} + (1 - \kappa^{iS})^{\frac{1}{\theta^{iS}}} (l_t^{iSQ})^{\frac{\theta^{iS}-1}{\theta^{iS}}} \right]^{\frac{\theta^{iS}}{\theta^{iS}-1}}.$$

Consumption is a composite of tradable goods and non-tradable services,

$$c_t^{iS} = f^c \left(c_t^{iS,T}, c_t^{iS,N} \right),$$

where tradables combine domestically produced goods ($T1$) and imports (F), and non-tradables combine low ($N1$)- and high ($N2$)-technology services.

Households with low ($j = U$) and medium ($j = X$) human capital solve an analogous problem but supply labor exclusively to production activities.

2.1.3 Households' First Order Conditions

The optimality conditions for the household problem for consumption $c_t^{ij,T}$ and their intertemporal consumption-savings decisions are standard and are identical across all household types $j = \{U, X, S\}$. These conditions imply that at the optimum, households equalize their marginal rate of substitution across consumption goods, adjusting for consumption taxes. The Euler condition shows how personal income taxes, by altering the after-tax return to savings, affect households' responses to idiosyncratic productivity shocks when smoothing consumption over time.

$$\begin{aligned} u_c(c_t^{ij}, l_t^{ij}) \frac{\partial c_t^{ij}}{\partial c_t^{ij,e}} &= \lambda_t^{ij} (1 + \tau_{c,t}^e) p_t^e \\ \lambda_t^{ij} &= \beta \mathbb{E}_t \lambda_{t+1}^{ij} \left[1 + r_{t+1} - \mathbb{T}_a(w_{t+1}^j l_{t+1}^{ij} \varepsilon_{t+1}^{ij}, (1 + r_{t+1}) a_{t+1}^{ij}) \right] \end{aligned}$$

The optimality conditions for labor differ across types, as high human capital workers can work in either research and production-so their optimization also includes conditions determining the optimal division of hours across these occupations- while other workers cannot. For households of type $j = \{U, X\}$ these conditions take the form:

$$u_l(c_t^{ij}, l_t^{ij}) = \lambda_t^{ij} [(1 - \tau_t^w) w_t^j \varepsilon_t^{ij} - \mathbb{T}_l(w_t^j l_t^{ij} \varepsilon_t^{ij}, (1 + r_t) a_t^{ij})]$$

while the corresponding conditions for households of type S are given by:

$$u_{l^{SP}}(c_t^{iS}, l_t^{iS}(l_t^{iSP}, l_t^{iSQ})) = \lambda_t^{iS} \left[(1 - \tau_t^w) w_t^{SP} \varepsilon_t^{iSP} - \mathbb{T}_{l^{SP}} \left(\begin{array}{c} w_t^{SP} l_t^{iSP} \varepsilon_t^{iSP} + w_t^{SQ} l_t^{iSQ} \varepsilon_t^{iSQ}, \\ (1 + r_t) a_t^{iS} \end{array} \right) \right],$$

$$u_{l^{SQ}}(c_t^{iS}, l_t^{iS}(l_t^{iSP}, l_t^{iSQ})) = \lambda_t^{iS} \left[(1 - \tau_t^w) w_t^{SQ} \varepsilon_t^{iSQ} - \mathbb{T}_{l^{SQ}} \left(\begin{array}{c} w_t^{SP} l_t^{iSP} \varepsilon_t^{iSP} + w_t^{SQ} l_t^{iSQ} \varepsilon_t^{iSQ}, \\ (1 + r_t) a_t^{iS} \end{array} \right) \right].$$

These conditions imply that for all workers the marginal rate of substitution between consumption and leisure is equal to their after-tax relative prices. Both payroll taxes τ^w , and higher income taxes reduce the effective return to working, and therefore distort intertemporal labor choices. For high human capital households, these conditions also imply that they allocate hours across production and research so that the marginal utility cost of supplying labor in each activity equals the corresponding after-tax marginal return.

Because research labor income is more uncertain, risk-averse households require higher expected wages to supply labor to R&D. This creates a key margin through which fiscal policy affects the allocation of talent across activities, and therefore the equilibrium supply of research labor and innovation outcomes.

2.2 Firms

We now turn to firms' production and innovation decisions. Firms produce output using capital, labor, intermediate inputs, and sector-specific technologies, and in high-technology sectors they endogenously invest in R&D to accumulate these technologies.

Firms specialize in the production of one of three types of goods: tradable goods ($T1$), non-tradable low-technology services ($N1$), and non-tradable high-technology services ($N2$).

Production in each sector uses capital $K_t^{P,e}$ and labor inputs $H_t^{j,e}$, where $e \in \{T1, N1, N2\}$ denotes the sector and $j \in \{U, X, S\}$ denotes the workers' human capital group. Not all types of workers are employed in every sector, and capital use differs across sectors. Low-technology

service firms ($N1$) employ only low- and medium-human-capital workers and do not use capital. High-technology services ($N2$) employ medium- and high-skilled labor, while tradable goods ($T1$) employ all skill types and are more capital intensive. Low- and medium-human-capital labor are more easily substituted for capital than high-human-capital labor. Labor and capital are freely mobile across sectors.

Firms in the high-technology sectors ($T1$ and $N2$) also use intermediate goods and services produced both within their own sector and by the other high-technology sector. For example, intermediate inputs used in the production of $T1$ are denoted $M_t^{T1,T1}$ and $M_t^{N2,T1}$, while those used in the production of $N2$ are denoted $M_t^{T1,N2}$ and $M_t^{N2,N2}$. In addition, firms in these sectors use sector-specific technologies, Q_t^{T1} and Q_t^{N2} , which are produced in house through R&D activity.

This structure captures input-output linkages across high-technology sectors, allowing innovation in one sector to affect production costs in others.

A key feature of the model is that these technologies enter production as an input, rather than as a purely multiplicative productivity term. This implies that changes in technology affect production not only through efficiency, but also through firms' input demand and substitution decisions.

All inputs are combined with sector-specific productivity, A^e , to generate output. Production functions are given by:

$$\begin{aligned} Y_t^{T1} &= \left(\bar{A}^{T1} \Theta_t^\zeta\right) \left[F^{T1} \left(K_t^{P,T1}, H_t^{U,T1}, H_t^{X,T1}, H_t^{S,T1}, M_t^{T1,T1}, M_t^{N2,T1} \right) \right]^\varsigma (Q_t^{T1})^{1-\varsigma} \\ Y_t^{N1} &= \left(\bar{A}^{N1} \Theta_t^\zeta\right) \left[F^{N1} \left(H_t^{U,N1}, H_t^{X,N1} \right) \right] \\ Y_t^{N2} &= \left(\bar{A}^{N2} \Theta_t^\zeta\right) \left[F^{N2} \left(K_t^{P,N2}, H_t^{X,N2}, H_t^{S,N2}, M_t^{T1,N2}, M_t^{N2,N2} \right) \right]^\varsigma (Q_t^{N2})^{1-\varsigma} \end{aligned}$$

In high-technology sectors, output depends on both standard inputs and the stock of sector-specific technology, with ς governing the relative importance of production inputs versus technology.

In sectors $e \in \{T1, N2\}$, firms invest in R&D to accumulate sector-specific technology. The stock of technology evolves according to

$$Q_t^e = (1 - \delta^Q) Q_{t-1}^e + I_t^{Q,e},$$

where $I_t^{Q,e}$ denotes expenditure on R&D and δ^Q is the depreciation rate of technology. Here, Q_t^e denotes the stock of sector-specific technology, while $I_t^{Q,e}$ denotes the flow of resources

devoted to producing that technology.

R&D expenditure combines research-specific capital $K_t^{Q,e}$ and high-skilled research labor $H_t^{Q,e}$ with baseline research productivity A^Q to produce new technology Q_t^e , implying that both inputs are necessary for innovation and only imperfectly substitutable:

$$I_t^{Q,e} = A^Q (K_t^{Q,e})^\varrho (H_t^{Q,e})^{1-\varrho},$$

The complementarity between research capital and research labor is central to the model's results, as it limits the extent to which firms can substitute capital for scarce scientific labor.

The total capital stock of firms,

$$K_t^e = K_t^{P,e} + K_t^{Q,e},$$

is the sum of capital used in production and in R&D and evolves according to

$$K_{t+1}^e = (1 - \delta^K) K_t^e + I_t^e,$$

where $I_t^e = I_t^{P,e} + I_t^{Q,e}$ denotes investment in physical capital and δ^K is its depreciation rate.

While the uses of capital are distinct in research and production, firms can freely reallocate capital across activities, although the tax treatment differs.

After-tax firm dividends are given by:

$$D_t^e = (1 - \tau_t^\pi) \Pi_t^e - K_{t+1}^{P,e} + K_t^{P,e},$$

where $K_{t+1}^{P,e} - K_t^{P,e}$ denotes net investment in production capital, which represents retained earnings in the context of this model. τ_t^π is the corporate income tax rate. R&D expenses net of the subsidy are expensed rather than capitalized. This treatment captures tax systems in which R&D expenditures are immediately deductible, implying that firms do not capitalize innovation investment in their financial accounts even though it generates future productivity gains.

Accounting profits are given by:

$$\begin{aligned} \Pi_t^e &= p_t^e Y_t^e - w_t^U H_t^{U,e} - w_t^X H_t^{X,e} - w_t^S H_t^{S,e} - \delta^K K_t^{P,e} - \tau_t^I I_t^{P,e} - \left(1 + \tau_t^{T1,e}\right) M_t^{T1,e} \\ &\quad - p_t^{N2} \left(1 + \tau_t^{N2,e}\right) M_t^{N2,e} - \left(1 - \tau_t^{Q,e}\right) \left(K_{t+1}^{Q,e} - (1 - \delta^K) K_t^{Q,e} + w_t^Q H_t^{Q,e}\right) \end{aligned}$$

where τ_t^I , $\tau_t^{T1,e}$, $\tau_t^{N2,e}$, and $\tau_t^{Q,e}$ denote the taxes on investment, intermediate goods from

sector $T1$, taxes on intermediate goods from sector $N2$, and the subsidy rate for $R\&D$ in sector e , respectively.

Firms maximize their value V^e , defined as the present discounted value of after-tax dividends:

$$V^e = \sum_{z=0}^{\infty} \frac{1}{1 + R_{t+z}} (1 - \tau_{t+z}^D) D_{t+z}^e$$

$$\max_{\substack{K_{t+z+1}^{P,e}, H_{t+z}^{U,e}, H_{t+z}^{X,e}, H_{t+z}^{S,e}, \\ M_{t+z}^{T1,e}, M_{t+z}^{N2,e}, Q_{t+z+1}^e, K_{t+z+1}^{Q,e}, H_{t+z}^{Q,e}}}$$

s.t.

$$K_{t+1}^e = (1 - \delta^K) K_t^e + I_t^e$$

$$Q_{t+1}^e = (1 - \delta^Q) Q_t^e + I_t^{Q,e}.$$

where τ_{t+z}^D is the dividend tax rate. The discount factor satisfies $1 + R_{t+z} = \prod_{ss=0}^{t+z} (1 + r_{ss})$.

2.2.1 Firm's First Order conditions

The first-order conditions characterize firms' optimal demand for labor, capital, intermediate inputs, and R&D inputs, taking taxes and subsidies as given. The firms' first order conditions imply the following:

- **Labor:** In each sector, firms hire labor up to the point at which the marginal product of each labor type equals its wage:

$$p_{t+z}^e \frac{\partial Y_{t+z}^e}{\partial H_{t+z}^{U,e}} = w_{t+z}^U, \quad p_{t+z}^e \frac{\partial Y_{t+z}^e}{\partial H_{t+z}^{X,e}} = w_{t+z}^X, \quad p_{t+z}^e \frac{\partial Y_{t+z}^e}{\partial H_{t+z}^{S,e}} = w_{t+z}^S$$

- **Capital:** The return on financial assets equals the after-tax marginal return to physical capital.

$$1 + r_{t+z+1} = \left(\frac{1 - \tau_{t+z+1}^D}{1 - \tau_{t+z}^D} \right) \left[\frac{1 + (1 - \tau_{t+z+1}^\pi) \left(p_{t+z+1}^e \frac{\partial Y_{t+z+1}^e}{\partial K_{t+z+1}^e} - \delta^K + \tau_{t+z+1}^I (1 - \delta^K) \right)}{1 + (1 - \tau_{t+z}^\pi) \tau_{t+z}^I} \right]$$

- **Intermediate Goods:** For sectors $e \in \{T1, N2\}$, firms demand intermediate inputs up to the point at which their marginal product equals their effective after-tax marginal cost. Taxes on intermediate inputs may arise from tax cascading, energy or carbon

taxes, upstream excise taxes, or—in the case of tradable goods—from tariffs.

$$p_{t+z}^e \frac{\partial Y_{t+z}^e}{\partial M_{t+z}^{T1,e}} = (1 + \tau_{t+z}^{T1,e}) p_{t+z}^{T1},$$

$$p_{t+z}^e \frac{\partial Y_{t+z}^e}{\partial M_{t+z}^{N2,e}} = (1 + \tau_{t+z}^{N2,e}) p_{t+z}^{N2}.$$

- **R&D:** Firms choose research capital and research labor so that the after-tax relative marginal cost of these inputs equals their marginal rate of technical substitution (equation 1). They also accumulate technology up to the point at which the marginal product of an additional unit of technology equals its after-tax marginal cost net of depreciation (equation 2).

These conditions imply that fiscal policy affects innovation through its impact on the cost of accumulating technology. Other things equal, R&D subsidies reduce the effective marginal cost of research inputs and technology accumulation, thereby encouraging innovation. However, because research capital and labor are complementary, the effectiveness of subsidies depends on the availability of high-human-capital workers. When research labor is scarce, subsidies primarily increase wages rather than expanding innovation. Dividend and corporate taxes affect R&D incentives primarily along transition paths. Through their impact on capital accumulation, they also have indirect effects in steady state. By contrast, the subsidy rate is the key determinant of long-run technology levels in the model.

$$1 + r_{t+z+1} - \left(\frac{1 - \tau_{t+z+1}^D}{1 - \tau_{t+z}^D} \right) \left(\frac{1 - \tau_{t+z+1}^\pi}{1 - \tau_{t+z}^\pi} \right) \left(\frac{1 - \tau_{t+z+1}^{Q,e}}{1 - \tau_{t+z}^{Q,e}} \right) (1 - \delta^K)$$

$$= \left(\frac{1 - \tau_{t+z+1}^D}{1 - \tau_{t+z}^D} \right) \left(\frac{1 - \tau_{t+z+1}^\pi}{1 - \tau_{t+z}^\pi} \right) \left(\frac{1 - \tau_{t+z+1}^{Q,e}}{1 - \tau_{t+z}^{Q,e}} \right) \frac{\varrho}{1 - \varrho} \frac{\left(K_{t+z+1}^{Q,e} \right)^{\varrho-1} \left(H_{t+z+1}^{Q,e} \right)^{1-\varrho}}{\left(K_{t+z}^{Q,e} \right)^\varrho \left(H_{t+z}^{Q,e} \right)^{-\varrho}}$$
(1)

$$p_{t+z+1}^e \frac{\partial Y_{t+z+1}^e}{\partial Q_{t+z+1}^e} = \frac{(1 - \tau_{t+z}^{Q,e}) w_{t+z}^Q}{1 - \varrho} \left[\left(\frac{1 - \tau_{t+z+1}^D}{1 - \tau_{t+z+1}^D} \right) \left(\frac{1 - \tau_{t+z+1}^\pi}{1 - \tau_{t+z+1}^\pi} \right) \frac{1 + r_{t+z+1}}{\left(K_{t+z}^{Q,e} \right)^\varrho \left(H_{t+z}^{Q,e} \right)^{-\varrho}} \right.$$

$$\left. - \left(\frac{1 - \tau_{t+z+1}^{Q,e}}{1 - \tau_{t+z}^{Q,e}} \right) \left(\frac{w_{t+z+1}^Q}{w_{t+z}^Q} \right) \frac{1 - \delta^Q}{\left(K_{t+z+1}^{Q,e} \right)^\varrho \left(H_{t+z+1}^{Q,e} \right)^{-\varrho}} \right]$$
(2)

This mechanism plays a central role in the quantitative results, where the interaction between R&D subsidies and labor supply determines whether innovation expands or is constrained by rising research wages.

2.3 Innovation

We now define aggregate innovation and its role in determining productivity across sectors. Aggregate innovation is an economy-wide object that summarizes the overall effectiveness of R&D activity in the economy. In the model, the stock of sector-specific technology, Q^e , is not by itself a sufficient statistic for innovation performance. While Q^e captures one dimension of innovative activity—the stock of usable technologies employed in production—innovation also depends on the amount of research capital devoted to creating new technologies and on the productivity of research labor.

Accordingly, aggregate innovation is defined as a function of the average technology stock, research capital, and scientist productivity. This distinction is important because policy changes may alter the composition and efficiency of research activity without generating one-for-one changes in the equilibrium stock of sector-specific technology. Formally, aggregate innovation is given by:

$$\Theta_t = \bar{Q}_t \bar{K}_t^Q \Gamma_t,$$

where \bar{Q}_t , \bar{K}_t^Q , and Γ_t denote the average levels across sectors of technology, research capital, and the average productivity of research labor (i.e., technology produced per scientist), respectively.

This formulation allows aggregate innovation to capture both innovation inputs, such as research capital and scientists, and innovation outcomes, such as the stock of usable technologies. It also reflects that innovation depends on the joint use of research inputs, so that changes in their relative costs can affect both the scale and efficiency of R&D activity.

As a result, policy changes may increase investment in research inputs while reducing the effective use of technology in production, implying that different measures of innovation need not move one-for-one.

The sector-specific productivity level A_t^e depends on the aggregate innovation stock according to

$$A_t^e(\Theta_t) = \bar{A}^e \Theta_t^\zeta, \tag{3}$$

where \bar{A}^e denotes baseline factor productivity in sector e , and ζ measures the extent to which innovation spills over into sectoral productivity.

This specification captures that innovation generates benefits beyond the firm or sector where it originates. As a result, policies that affect R&D incentives influence not only firm-level innovation, but also aggregate productivity through general equilibrium effects. Intuitively, the stock of sector-specific technology captures the quantity of ideas available for production, while aggregate innovation reflects how effectively these ideas are generated and translated into productivity, given the allocation of research inputs. This distinction is central for understanding why policy can increase R&D inputs without generating proportional changes in measured technology or output.

2.4 Government

The government uses fiscal instruments that affect both firms' innovation decisions and households' labor supply and consumption choices.

On the household side, it levies taxes on labor income, capital income, and consumption. On the firm side, it imposes dividend taxes, corporate income taxes, taxes on intermediate inputs, and provides R&D subsidies. These policies affect innovation both directly, by altering firms' incentives to invest in R&D, and indirectly, by influencing the supply and allocation of high-human-capital workers across activities.

The government issues domestic debt, which follows an exogenous path, and finances expenditures on goods, and services, and provides transfers to households. The government's budget constraint is given by:

$$\Xi_t^C + \Xi_t^{inc} + \Xi_t^w + \Xi_t^M + \Xi_t^D + \Xi_t^\pi + \Xi_t^I - \Xi_t^Q + (1 + r_t) B_t = Trans_t + G_t^{T1} + p_t^{N1} G_t^{N1} + p_t^{N2} G_t^{N2} + B_{t+1} \quad (4)$$

where Ξ_t^C , Ξ_t^{inc} , Ξ_t^w , Ξ_t^M , Ξ_t^D , Ξ_t^π , and Ξ_t^I denote revenues from consumption taxes, personal income taxes, payroll taxes, intermediate input taxes, dividend taxes, corporate income taxes, and investment taxes, respectively. Ξ_t^Q denotes government expenditures on R&D subsidies. $Trans_t$ corresponds to government transfers to households, while G_t^{T1} , G_t^{N1} , and G_t^{N2} correspond to government expenditures on tradable goods and low and high-technology services, respectively. Finally, B_t indicates the stock of domestic government debt outstanding at the beginning of period t .

2.5 Stationary Competitive Equilibrium

We define a stationary competitive equilibrium for this economy with heterogeneous households, endogenous occupational choice, and innovation-driven production.

The aggregate state of the economy is summarized by a joint measure $\vartheta \in \Omega$ over households' individual state variables. Households are heterogeneous with respect to their human capital group $j \in \{U, X, S\}$, their idiosyncratic labor productivity $\varepsilon \in \aleph^j$, and their asset holdings $a \in \mathbf{A}^j := [-\kappa^j, \infty)$. Let

$$\mathbf{A} = \mathbf{A}^U \times \mathbf{A}^X \times \mathbf{A}^S, \quad \aleph = \aleph^U \times \aleph^X \times \aleph^S, \quad \Phi = \mathbf{A} \times \aleph.$$

Let $\mathcal{B}(\mathbf{A})$ denote the Borel σ -algebra on \mathbf{A} and $\mathcal{P}(\aleph)$ the power set of \aleph . The set Ω denotes the collection of all finite measures defined on the measurable space $(\Phi, \mathcal{B}(\mathbf{A}) \times \mathcal{P}(\aleph))$.

Given exogenous prices and government policies—including the international price of imported goods p^F , tax instruments, transfers, government expenditures, and public debt—a stationary competitive equilibrium consists of:

- household value functions and policy rules $\{V^j, c^j(a, \varepsilon), l^j(a, \varepsilon), l^{P,j}(a, \varepsilon), l^{Q,j}(a, \varepsilon), a'^j(a, \varepsilon)\}$. For $j \in \{U, X\}$, households do not work in research, so $l^{Q,j}(a, \varepsilon) = 0$ and $l^{P,j}(a, \varepsilon) = l^j(a, \varepsilon)$;
- firm production and research plans $\{H^{U,e}, H^{X,e}, H^{S,e}, H^{Q,e}, M^{T1,e}, M^{N2,e}, K^{P,e}, K^{Q,e}, Q^e, Y^e\}$ for each sector $e \in \{T1, N1, N2\}$;
- prices $\{w^U, w^X, w^S, w^Q, p^{N1}, p^{N2}, r\}$;
- and a stationary distribution $\vartheta \in \Omega$;

such that the following conditions hold:

- **Household problem.** For each human-capital group $j \in \{U, X, S\}$, household decisions are characterized by policy functions defined over individual states (a, ε) . Let p^c denote the consumption price index associated with the consumption aggregator $c = f^c(c^T, c^N)$, where prices are given by $p^{T1} = 1$, p^F , p^{N1} , and p^{N2} . The price index p^c is defined as the minimum expenditure required to purchase one unit of the composite consumption good. Households allocate total consumption expenditure across goods to minimize cost, taking prices and consumption taxes as given. The value function

$V^j(a, \varepsilon)$ solves

$$V^j(a, \varepsilon) = \max_{c, l, l^P, l^Q, a'} \left\{ u(c, l) + \beta \int V^j(a', \varepsilon') \mathbb{Q}^j(\varepsilon, d\varepsilon') \right\}$$

$$\begin{aligned} \text{s.t. } (1 + \tau_c)p^c c + a' &= (1 - \tau^w)(\varepsilon^P w^{P,j} l^P + \varepsilon^Q w^{Q,j} l^Q) + (1 + r)a - \mathbb{T}(\cdot), \\ (1 + \tau_c)p^c c &= (1 + \tau_c^{T1})c^{T1} + (1 + \tau_c^F)p^F c^F + (1 + \tau_c^{N1})p^{N1}c^{N1} + (1 + \tau_c^{N2})p^{N2}c^{N2}, \\ c &= f^c(c^T, c^N), \quad c^T = f^{cT}(c^{T1}, c^F), \quad c^N = f^{cN}(c^{N1}, c^{N2}), \\ l &= f^l(l^P, l^Q), \\ a' &\geq -\kappa^j, \quad c > 0, \quad 0 \leq l, l^P, l^Q \leq 1. \end{aligned}$$

- **Firms.** Factor prices $\{w^U, w^X, w^S, w^Q, r\}$ satisfy firms' first-order conditions for labor, capital, technology, and intermediate inputs in each sector e .
- **Government budget.** The government budget constraint holds with equality, with tax revenues and transfers defined as

$$\begin{aligned} \Xi^C &= \sum_j \int \left[\tau_c^{T1} c^{j,T1} + \tau_c^{N1} p^{N1} c^{j,N1} + \tau_c^{N2} p^{N2} c^{j,N2} \right] \vartheta^j(da d\varepsilon), \\ \Xi^{inc} &= \sum_j \int \mathbb{T}^j(\cdot) \vartheta^j(da d\varepsilon), \\ \Xi^w &= \sum_j \int \tau^w (\varepsilon^P l^{P,j} + \varepsilon^Q l^{Q,j}) \vartheta^j(da d\varepsilon), \\ Trans &= \sum_j \int Trans^j \vartheta^j(da d\varepsilon), \\ \Xi^D &= \tau^D \sum_e D^e, \quad \Xi^\pi = \tau^\pi \sum_e \Pi^e, \quad \Xi^I = \tau^I \sum_e I^e, \quad \Xi^Q = \tau^Q \sum_e I^{Q,e}. \end{aligned}$$

- **Market clearing.** Markets clear in financial, labor, and goods markets as follows:
Financial markets:

$$\begin{aligned} K + Q + B &= \sum_j \int a \vartheta^j(da d\varepsilon), \\ K &= K^P + K^Q, \\ K^P &= K^{P,T1} + K^{P,N2}, \quad K^Q = K^{Q,T1} + K^{Q,N2}, \\ Q &= Q^{T1} + Q^{N2}. \end{aligned}$$

where K and Q denote the aggregate value of physical capital and technology, respectively, held by firms, and B denotes government debt held by households.

Labor markets:

$$\begin{aligned} H^U &= H^{U,N1} + H^{U,T1} = \nu^U \int \varepsilon l^U \vartheta^U(da d\varepsilon), \\ H^X &= H^{X,N1} + H^{X,T1} + H^{X,N2} = \nu^X \int \varepsilon l^X \vartheta^X(da d\varepsilon), \\ H^{S,P} &= H^{S,P,T1} + H^{S,P,N2} = \nu^S \int \varepsilon l^{S,P} \vartheta^S(da d\varepsilon), \\ H^{S,Q} &= H^{S,Q,T1} + H^{S,Q,N2} = \nu^S \int \varepsilon l^{S,Q} \vartheta^S(da d\varepsilon). \end{aligned}$$

The efficiency parameters satisfy $0 < \nu^U < \nu^X < \nu^S$ and capture differences in effective labor units across skill groups.

Domestic Goods markets:

$$\begin{aligned} Y^{N1} &= \sum_j \int c^{j,N1} \vartheta^j(da d\varepsilon) + G^{N1}, \\ Y^{N2} &= \sum_j \int c^{j,N2} \vartheta^j(da d\varepsilon) + M^{N2,T1} + M^{N2,N2} + G^{N2}, \end{aligned}$$

Tradable Goods Market / External Balance:

$$Y^{T1} = \sum_j \int c^{j,T1} \vartheta^j(da d\varepsilon) + M^{T1,T1} + M^{T1,N2} + I^{T1} + I^{N2} + G^{T1} - IM^{T1},$$

where IM^{T1} denotes net imports of tradable goods $T1$. Total imports are given by

$$IM = IM^F + IM^{T1},$$

where

$$IM^F = p^F \sum_j \int c^{j,F} \vartheta^j(da d\varepsilon)$$

denotes imports of foreign consumption goods F , which are not produced domestically. Under the assumption of zero net foreign assets, the trade balance is zero in every period, so net imports adjust endogenously to satisfy external balance.

- **Law of motion of the distribution.** The distribution of households evolves accord-

ing to

$$\vartheta' = H^\vartheta(\vartheta),$$

where for any measurable sets $\mathcal{A} \subseteq \mathbf{A}$ and $\mathcal{E} \subseteq \mathfrak{N}$,

$$\vartheta'(\mathcal{A} \times \mathcal{E}) = \sum_j \int \mathbf{1}\{a'(a, \varepsilon, j) \in \mathcal{A}\} \mathbb{Q}^j(\mathcal{E} \mid \varepsilon) \vartheta^j(da d\varepsilon).$$

In a stationary equilibrium, the distribution is invariant, so that $\vartheta' = \vartheta$.

The distribution ϑ can be decomposed into type-specific measures $\{\vartheta^j\}_{j \in \{U, X, S\}}$, where each ϑ^j is defined over (a, ε) for households of type j .

3 Calibration

The model is calibrated to match key features of the Canadian economy, including sectoral composition, R&D intensity, the distribution of skills and income, and the structure of the tax system. All parameters are chosen to jointly replicate a set of aggregate and cross-sectional moments. Additional details on data sources, functional forms, and parameter construction are provided in Appendix B.

3.1 Calibration Strategy

The calibration proceeds in three blocks: production and innovation, household behavior, and fiscal policy.

On the production side, parameters are chosen to match sectoral shares of output, input intensities, and the relative importance of technology across sectors using Canadian Supply and Use Tables. The model targets differences in capital intensity and skill composition across tradable goods, low-technology services, and high-technology services, as well as observed R&D expenditure and employment shares.

Household-side parameters are calibrated to match the distribution of education groups, wage premia across skill levels, and the distribution of market income. Idiosyncratic productivity processes are chosen to replicate the empirical income distribution. Preference parameters are set to standard values in the literature and to match aggregate labor supply and consumption patterns.

Fiscal policy parameters are calibrated to reflect the Canadian tax system. This includes personal income taxes, consumption taxes, corporate taxation, and R&D subsidies. The

calibration targets both average tax rates and progressivity, as well as the relative importance of different revenue sources.

3.2 Key Targets

The calibration matches the following key moments in the data:

- Sectoral shares of GDP and expenditure components,
- Input shares of labor, capital, and intermediate goods across sectors,
- R&D intensity (as a share of GDP) and employment in research occupations,
- Population shares by education group and associated wage premia,
- The distribution of market income across households,
- Effective tax rates on labor income, consumption, capital, and R&D.

The model provides a close fit to these moments. In particular, it replicates the relative size of the high-technology sector, the share of workers engaged in R&D activities, and the dispersion of income across households. Minor discrepancies arise from modeling abstractions, such as the absence of firm heterogeneity and financial frictions.

3.3 Key Parameters

Several parameters play a central role in the quantitative results.

First, the elasticity of substitution between capital and different types of labor governs how production responds to changes in relative factor prices. The calibration allows for greater complementarity between capital and high-skilled labor, consistent with empirical evidence.

Second, the parameters governing R&D production are chosen to match both the share of employment in research activities and the relative size of investment in intangible capital. These parameters determine the responsiveness of innovation to policy incentives.

Third, preference and occupational choice parameters govern labor supply and the allocation of high-skilled workers between production and research. These parameters are key for determining the elasticity of the supply of scientists, which is central to the paper's mechanism.

Finally, fiscal parameters—including the level and progressivity of income taxation and the generosity of R&D subsidies—are calibrated to match institutional features of the Canadian economy.

A full list of parameters, calibration targets and other details is reported in Appendix B.

4 Results

Before presenting the quantitative results, it is useful to clarify their interpretation. The magnitudes reported below reflect long-run equilibrium differences across policy regimes rather than short-run responses. They should therefore be understood as the cumulative effects of policy operating through capital accumulation, occupational choice, and general equilibrium price adjustments. While some of the quantitative effects are sizable, they arise from the interaction of multiple general equilibrium channels operating over the long run, including capital accumulation, sectoral reallocation, and endogenous labor supply responses.

4.1 R&D Subsidies, τ^Q

We use the model to compare steady-state equilibria that differ in their R&D subsidy rates. The analysis highlights a central mechanism of the paper: when the supply of high-human-capital workers is limited, R&D subsidies can reduce innovation and long-run growth by exacerbating talent bottlenecks.

4.1.1 Fixed Labor Supply

Under the assumption that the supply of high-human-capital workers is fixed and innovation does not generate economy-wide spillovers (i.e., $\zeta = 0$ in equation (3)), Figure 1, panels A and B, report the responses of innovation and output growth to changes in R&D subsidies relative to a zero-subsidy baseline ($\tau^Q = 0$). Reducing the effective R&D tax—from roughly 13.7% to about 3.8%—raises innovation by about 20% and long-run output growth by 5.4%, reflecting the removal of distortions in research capital accumulation ($K^{Q,e}$) without a substantial increase in research wages (w^Q).

However, as subsidies become more generous, their effects reverse. At a subsidy rate of 15.2%, innovation falls about 7 percentage points below baseline, and GDP approaches levels observed when R&D is taxed at the same rate as physical capital (13.7%). At the Canadian-level subsidy (30.6%), innovation declines by roughly 19% and long-run GDP growth by 13.8%, reflecting the binding constraint imposed by the limited supply of scientists.

These results show that when the supply of high-human-capital workers is fixed, higher R&D subsidies increase research capital ($K^{Q,e}$) but reduce the effective use of research labor. By raising the demand for scientists, subsidies bid up their wages (w^Q), making research labor increasingly costly. Firms substitute toward research capital; however, capital cannot fully replace labor in the production of new technologies. As a result, technology creation (Q^e) and output (Y^e) do not increase proportionally, and average researcher productivity ($\Gamma = \sum_e \frac{Q^e}{H^{Q,e}}$) declines.

The implications of this mechanism are visible in factor prices and investment patterns.

As firms compete for scarce R&D workers, wages in scientific occupations (w^Q) rise sharply, largely offsetting the subsidy and limiting the decline in the effective cost of R&D investment ($I^{Q,e}$). Figure 1, panel C, shows that scientists' wages increase rapidly across all subsidy levels, while wages for other workers decline more moderately. These wage dynamics reflect the inelastic supply of research labor and limit the effectiveness of subsidies in expanding R&D activity.

Research capital grows across the subsidy spectrum, as illustrated in Figure 1, panel D. However, production capital ($K^{P,e}$) and total capital ($K^e = K^{P,e} + K^{Q,e}$) increase only when R&D taxes are eliminated and decline once subsidies become positive. This reflects substitution away from production capital and toward research capital as its effective cost falls, while weaker economic activity reduces incentives to invest in expanding production.

Aggregate technology remains relatively constant when R&D taxes are removed, but declines as subsidies increase—especially in the tradable sector—because firms cannot expand research employment sufficiently. As research activity becomes more expensive, firms are unable to expand research employment sufficiently, and some scientists reallocate toward production. Since services are more intensive in high-human-capital labor, this reallocation partially offsets the contraction in that sector, leading to a more pronounced decline in technology production in tradables.

Total R&D spending exhibits strong crowding out: public spending increases while private R&D declines. At the Canadian subsidy rate (30.6%), the decline in private R&D (as a share of GDP) is 2.66 times larger than the increase in public R&D relative to baseline.

Consistent with the literature emphasizing the role of talent allocation and human capital in innovation (e.g., Akcigit et al., 2020; Van Reenen, 2021), these results highlight that talent bottlenecks can limit the effectiveness of R&D subsidies: when high-skill labor supply is inelastic, subsidies primarily bid up wages and crowd out private investment rather than expanding innovation.

Figure 2 shows the distributional impact of the policy. Panel A reports the top-to-

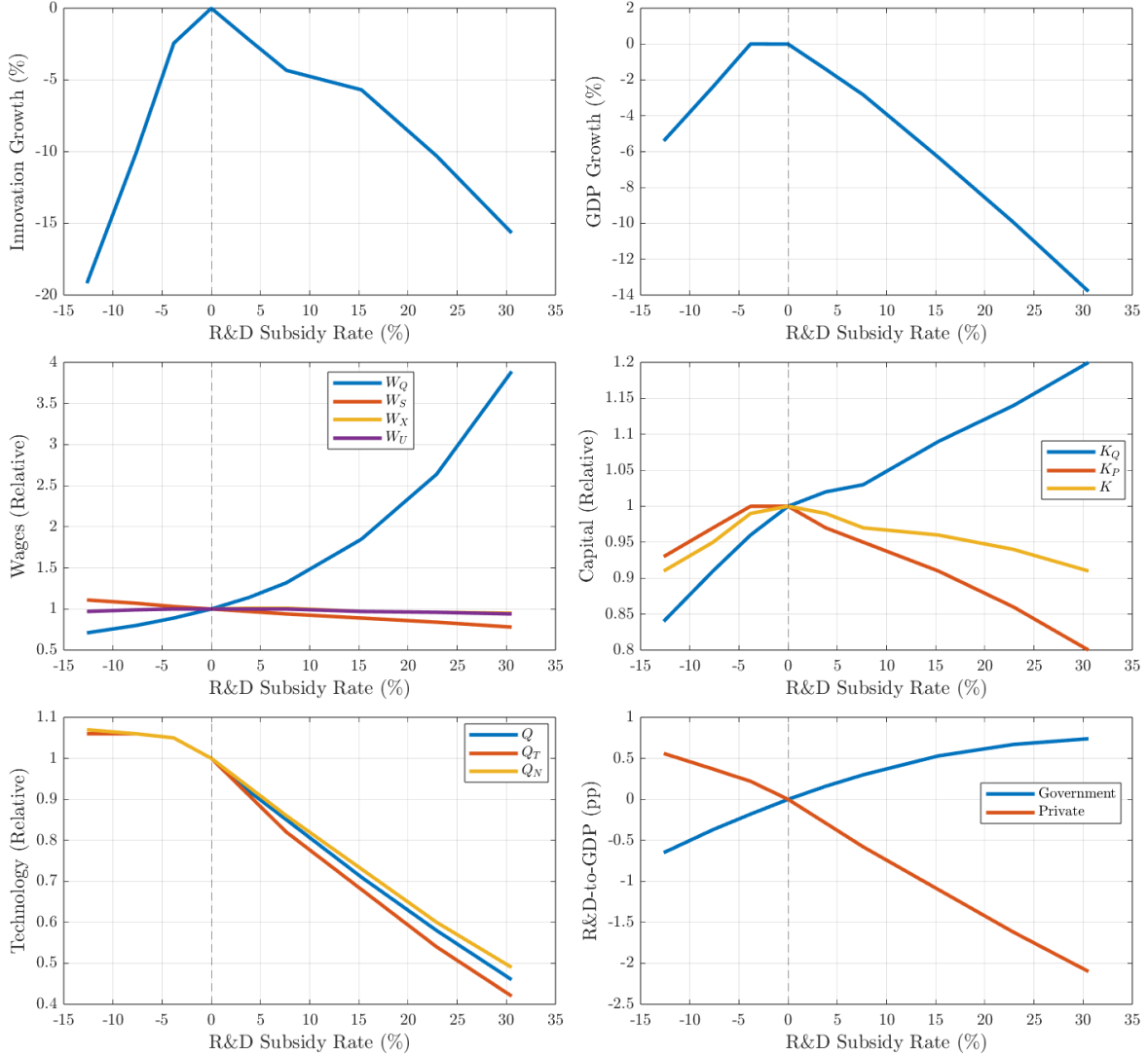


Figure 1: Effects of R&D Subsidies on Innovation and Long-Run Growth. The figure reports steady-state outcomes relative to the zero-subsidy baseline. Panel (A) shows innovation growth. Panel (B) shows GDP growth. Panel (C) reports relative wages by skill group. Panel (D) shows capital stocks. Panel (E) presents technology levels. Panel (F) reports government and private R&D expenditures as a share of GDP.

bottom decile ratio (P90/P10) for income and consumption. These ratios rise monotonically with R&D subsidies when labor supply is fixed, as higher subsidies disproportionately raise scientists' wages. Panel B shows that both the poverty rate and Gini coefficient increase with subsidy generosity, reflecting both greater dispersion in incomes and lower aggregate output.

The distributional effects follow directly from the same mechanism. Higher subsidies increase demand for scarce research labor, raising scientists' wages—workers who already earn above-average incomes and represent a small share of the population. This increases income concentration at the top, as reflected in higher P90/P10 ratios and the Gini coefficient.

At the same time, the decline in aggregate output shifts the entire income distribution downward. As GDP falls, some households near the poverty threshold in the baseline fall below it, increasing the poverty rate. Unlike inequality, poverty is not strictly monotonic in subsidies: sufficiently high R&D taxes (i.e., negative subsidies) also increase poverty because they reduce output relative to the baseline.

These results highlight that policies targeting innovation can have significant distributional consequences when they interact with constraints in the supply of high-skill labor.

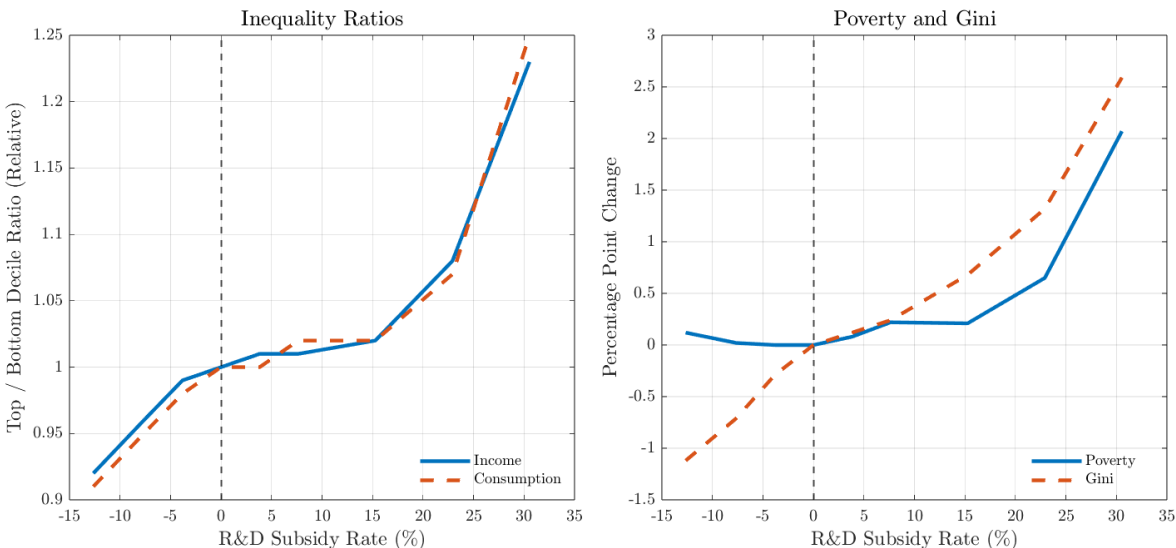


Figure 2: Distributional Effects of R&D Subsidies with Fixed Labor Supply. Panel (A) reports the top-to-bottom decile ratios for income and consumption relative to baseline. Panel (B) reports percentage-point changes in the poverty rate and Gini coefficient.

4.1.2 Flexible Labor Supply

We now consider an economy without spillovers from innovation in which the supply of high-human-capital labor responds to research wages according to empirical estimates of human capital supply elasticities (Evers et al., 2008).³

Figure 3 compares outcomes under fixed and flexible labor supply. When labor supply is elastic, R&D subsidies generate positive long-run growth effects, as they expand the pool of scientists and increase effective innovation. Even without spillovers, the Canadian-level subsidy increases innovation growth by 50% relative to the zero-subsidy baseline, whereas taxing R&D reduces innovation by roughly 20%. Long-run GDP growth rises by 14.4% under flexible labor supply, but declines when labor supply is fixed.

Scientist wages rise less sharply under flexible labor supply (by a factor of 2.5 compared to fourfold under fixed supply), as the expansion in the pool of high-human-capital workers alleviates the scarcity of research labor. This allows subsidies to translate more effectively into higher innovation rather than primarily increasing wage premia. As a result, research capital expands more strongly ($1.5\times$ baseline vs $1.2\times$ when fixed), and total capital rises as well ($1.2\times$ baseline). Differences between flexible and fixed labor supply economies widen as subsidies increase: at the Canadian subsidy rate, the level of technology under flexible labor supply is more than 60% higher than under fixed supply, and private R&D as a share of GDP is about 0.5 percentage points higher than under fixed labor supply.

The fact that Q^e may fall relative to the benchmark does not imply that innovation declines. Because Q^e enters production as one input among others, its equilibrium level reflects both its cost of creation and its marginal value in production. Subsidies can therefore improve innovation performance by increasing the efficiency and capital intensity of research activity, even if the equilibrium stock of sector-specific technology is lower than in the no-subsidy benchmark.

Figure 4 presents the distributional implications. Generous subsidies raise inequality and poverty in both scenarios, but the effects are substantially stronger when labor supply is fixed. When labor supply is elastic, higher research wages induce some mid-human-capital workers to acquire additional skills and enter research occupations, expanding the pool of scientists. This dampens wage increases for scientists and reduces the dispersion between the top and bottom of the distribution relative to the fixed labor supply case.

³Specifically, using a wage elasticity of 0.1, consistent with Evers et al., 2008, we iteratively compute updated shares of high-human-capital workers and the corresponding equilibrium scientist wages until convergence for each subsidy rate. The share of high-human-capital workers increases at the expense of mid-human-capital workers.

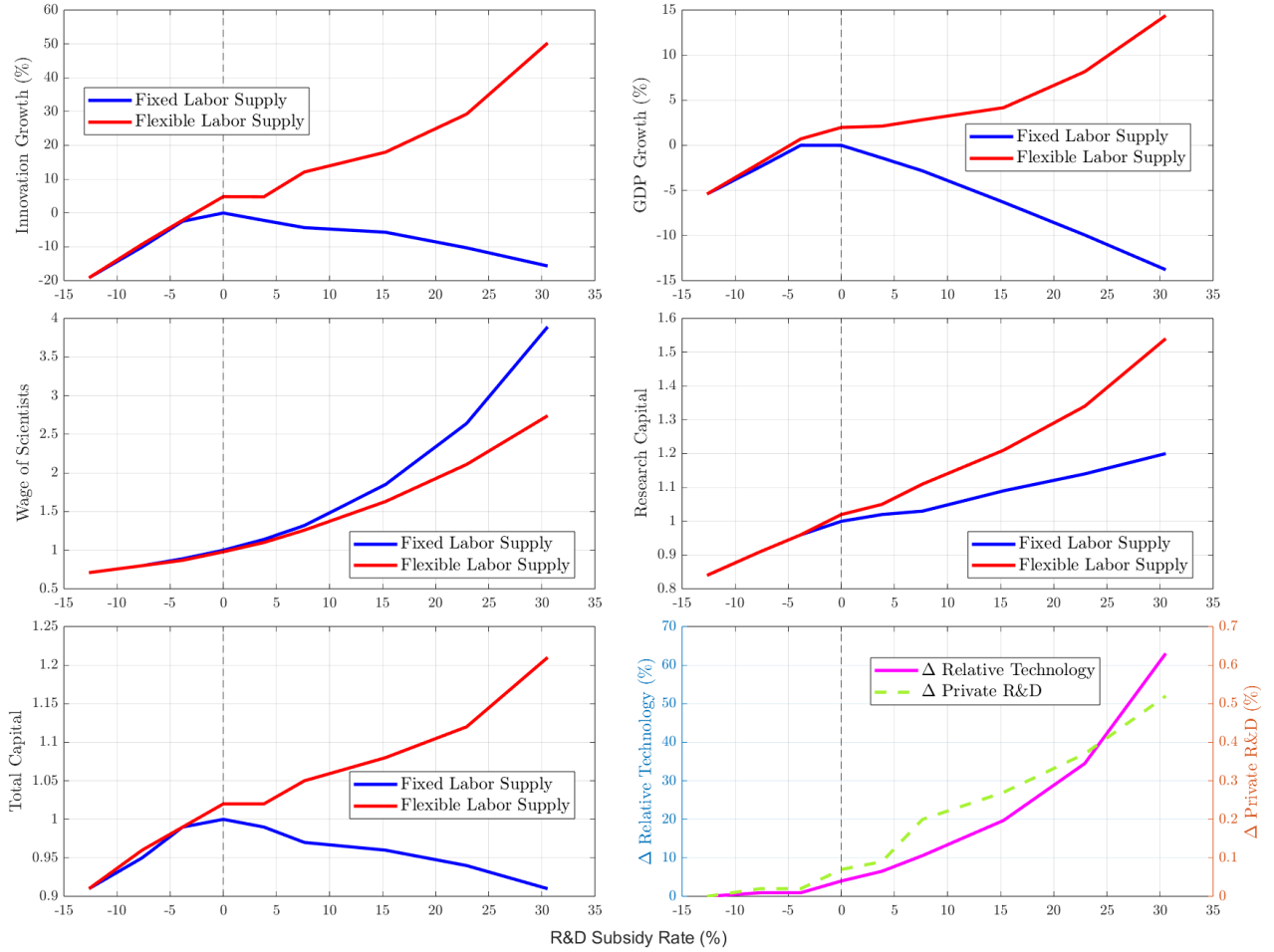


Figure 3: Comparison of R&D Subsidy Effects under Fixed vs Flexible Labor Supply. All results are expressed relative to the zero-subsidy baseline of the economy with fixed population shares. Panel (A) shows innovation growth. Panel (B) shows GDP growth. Panel (C) shows relative wages of scientists. Panel (D) shows research capital stocks. Panel (E) shows total capital stocks. Panel (F) shows technology differences in percentage terms and private R&D intensity differences between flexible and fixed scenarios.

At the same time, higher GDP levels shift the overall income distribution upward. Although increased dispersion still pushes some households below the poverty line, the rise in poverty is smaller than under fixed labor supply. Policies that expand the supply of high-human-capital workers therefore mitigate the adverse distributional effects of R&D subsidies by easing wage pressures in research occupations and supporting aggregate income.

These results highlight that both the effectiveness and the distributional consequences of R&D subsidies depend critically on the responsiveness of high-skill labor supply.

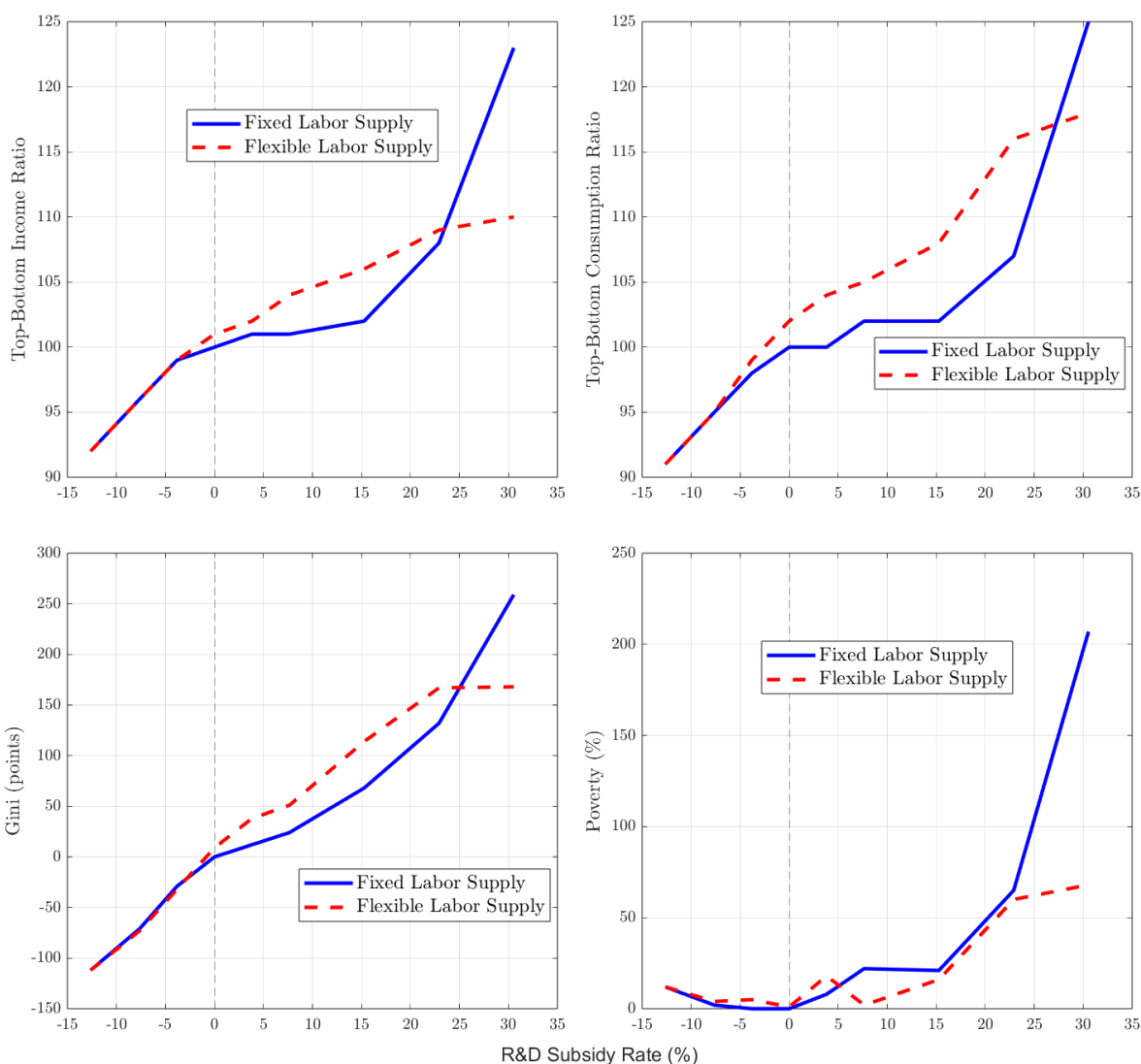


Figure 4: Distributional Effects of R&D Subsidies under Fixed vs Flexible Labor Supply. Panel (A) reports top-to-bottom decile ratios for income and consumption. Panel (B) reports percentage-point changes in the poverty rate and Gini coefficient.

4.1.3 Knowledge Spillovers

The previous results abstract from knowledge spillovers generated by innovation. Incorporating such spillovers amplifies the effects of R&D subsidies by linking sectoral innovation to aggregate productivity. Specifically, higher R&D activity raises the economy-wide stock of knowledge, which in turn increases total factor productivity (TFP). The strength of this amplification is governed by the elasticity of TFP with respect to innovation, ζ .

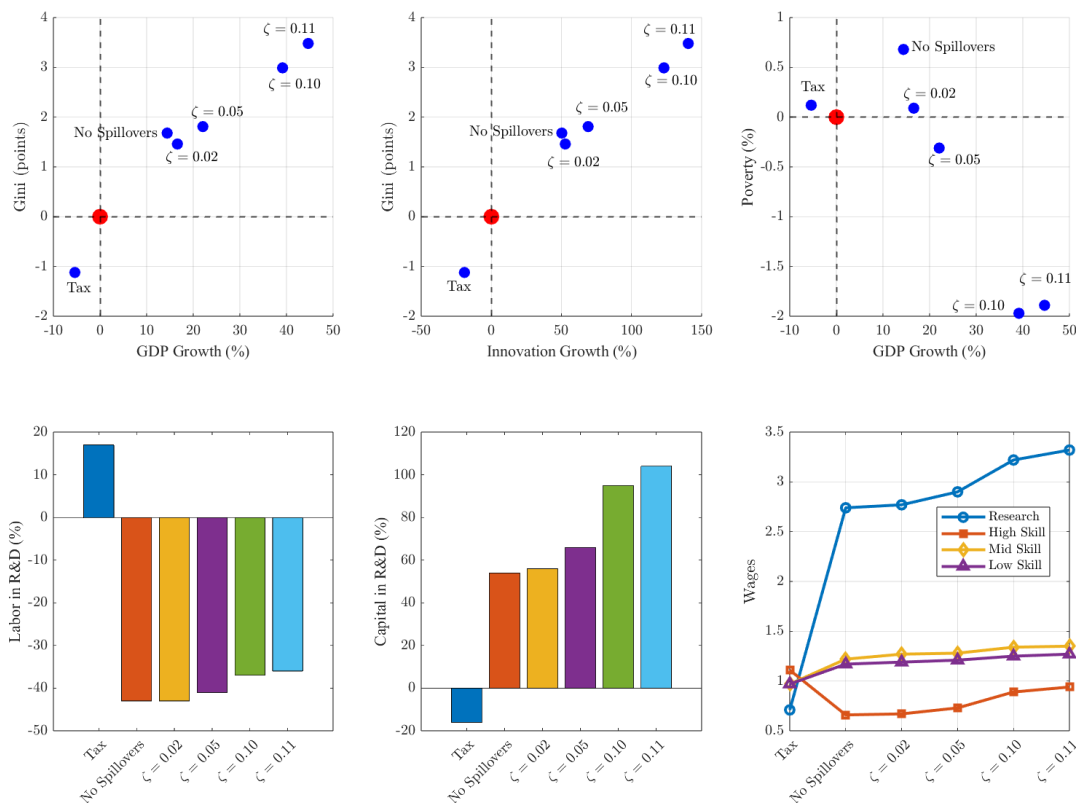


Figure 5: Comparison of R&D Subsidy Effects under spillovers and no spillovers. These results assume labor supply is held constant at the level observed in an economy without spillovers, where labor supply has already adjusted in response to the R&D subsidies. All results are expressed relative to the zero-subsidy baseline of the economy with fixed population shares. Panel (A) shows GDP growth and Gini changes. Panel (B) shows innovation growth and Gini changes. Panel (C) shows GDP growth and poverty rate changes. Panel (D) shows research labor. Panel (E) shows research capital stocks. Panel (F) shows relative wages.

Figure 5 shows equilibrium innovation and growth outcomes as well as changes in the Gini coefficient, the poverty rate, labor and capital in R&D, and relative wages under alternative

values of ζ , assuming the Canadian subsidy rate (30.54%).

The range of ζ values considered is consistent with Social Return Rates to Innovation (SRRI) ranging between 14.9% and 50%. Empirical estimates of the SRRI typically range from 20-50% and occasionally exceed 100%.⁴

Using the approach in Jones and Summers, 2020, and accounting for the contribution of capital deepening to TFP growth as well as the delays between R&D expenditures and their impact on TFP, we estimate an SRRI of 23% for Canada over the period 2010–2022. This implies $\zeta = 0.05$.⁵

Innovation and growth increase with the strength of spillovers, while poverty tends to decline and inequality tends to rise.

At the Canadian subsidy rate, long-run GDP growth increases from 14% in an economy without spillovers to 22% when the SRRI is around 23% ($\zeta = 0.05$), and to about 45% when the SRRI reaches 50% ($\zeta = 0.11$). Innovation rises from 50% without spillovers to 69% with an SRRI of 23%, and to 240% when the SRRI is 50%.

Poverty declines as spillovers increase, although the relationship is not monotonic due to competing effects from capital–labor substitution that tend to negatively impact the earnings of workers with less human capital. In addition, labor supply is not fully endogenous in this setup, which limits social mobility.

Relative to an economy without spillovers, the presence of spillovers increases the demand for research inputs and raises the size of the research sector. However, the research workforce remains smaller than in an economy without R&D subsidies, as higher researcher wages induced by subsidies lead firms to substitute toward research capital. Research capital, in contrast, grows more rapidly with spillovers, reflecting both higher returns to innovation and stronger incentives to accumulate research inputs.

Wages for all workers are higher in an economy with spillovers than in one without. The decline in the wages of high-human-capital workers in production, relative to the baseline, reflects the assumed initial increase in their share of the population and therefore in their labor supply in response to higher research wages.

Overall, these results likely underestimate the positive effects of R&D subsidies in the presence of spillovers. The absence of a second-round labor supply response from high-human-capital workers limits firms' ability to expand research activity. If labor supply were fully flexible, equilibrium research wages would increase less, while other wages would

⁴See, for example, Hall et al., 2010, Bloom et al., 2013, and Jones and Summers, 2020.

⁵The elasticity ζ satisfies $\zeta = SRRI \times (R\&D/GDP) \times \beta^{\text{years lag}}$, where years lag denotes the time required for innovation to affect TFP.

rise more, supporting higher innovation and growth as well as lower wage dispersion and inequality.

Figure 6 presents results for $\zeta = 0.05$ across different subsidy rates. Accounting for spillovers amplifies the benefits of R&D subsidies at all levels. For example, long-run GDP gains of 14.4%—achieved at the Canadian subsidy rate of 30.6% in an economy without spillovers—can be attained with a lower subsidy rate of 22.1% when spillovers consistent with an SRRI of 23% ($\zeta = 0.05$) are included.

The quantitative importance of accounting for spillovers when evaluating R&D subsidies relative to other policies is substantial. For comparison, estimates suggest that removing internal trade barriers within Canada—a structural reform that has received broad public and private support—would increase GDP by roughly 6%. This is less than half of the gains implied by the model without spillovers and only about one-seventh of the gains under plausible spillover magnitudes (e.g., when the SRRI is around 50%).

The analysis also abstracts from potential differences in the social returns to public and private R&D spending. Empirical evidence suggests that public R&D may generate larger spillovers than private-sector innovation in some contexts (e.g., Fieldhouse and Mertens, 2024; Bloom et al., 2013). Allowing for heterogeneous spillovers across types of R&D would likely affect the quantitative magnitude of optimal subsidies and the implied welfare gains from innovation policy. However, the central mechanism emphasized in the paper would remain: when research labor is relatively scarce and complementary to research capital, stronger innovation incentives continue to place upward pressure on scientist wages, limiting the extent to which subsidies translate into additional innovation and growth. More generally, an interesting extension would be to study whether advances in artificial intelligence alter the complementarity between research capital and scientific labor, potentially relaxing some of the talent constraints emphasized in this paper.

4.1.4 The Share of High-Human Capital Workers in the Economy

The previous results highlight the importance of the supply of high-human-capital workers. To further isolate this mechanism, we consider economies with the same R&D subsidy rate (equal to the Canadian level) but different fixed shares of high-human-capital workers. Figure 7 reports the resulting outcomes.

Innovation and economic growth increase with the share of high-human-capital workers. As this share rises, the scarcity of research labor declines, reducing wages for scientists and for high-human-capital workers in production, while increasing wages for other workers. This rebalancing of factor prices allows firms to expand both research and production capital,

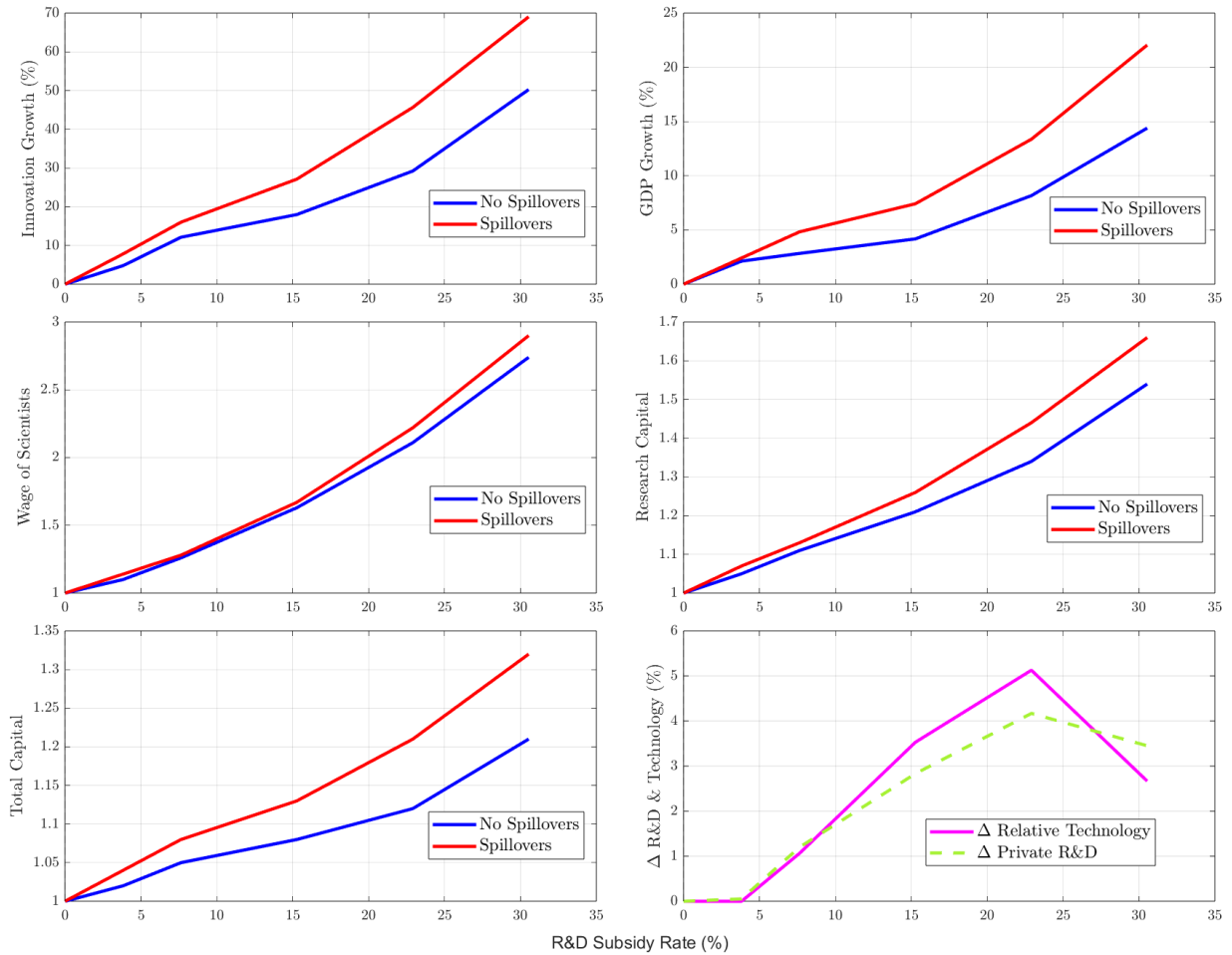


Figure 6: Comparison of R&D Subsidy Effects under spillovers and no spillovers. These results assume labor supply is held constant at the level observed in an economy without spillovers, where labor supply has already adjusted in response to the R&D subsidies. All results are expressed relative to the zero-subsidy baseline of the economy with fixed population shares. Panel (A) shows innovation growth. Panel (B) shows GDP growth. Panel (C) shows relative wages of scientists. Panel (D) shows research capital stocks. Panel (E) shows total capital stocks. Panel (F) shows technology differences in percentage terms and private R&D intensity differences between flexible and fixed scenarios.

leading to higher levels of technology and output.

The quantitative implications are substantial. For an economy with characteristics similar to Canada, where the share of high-human-capital workers is about 7%, R&D subsidies reduce innovation and economic growth. In contrast, in an otherwise identical economy with a share comparable to that of the United States (17%)—based on Census data and our definition of high-human capital—R&D subsidies generate long-run increases in innovation of about 60% and in economic growth of about 40%, even without accounting for knowledge spillovers.

In terms of distributional outcomes, a higher share of high-human-capital workers is associated with lower inequality. Top-to-bottom income ratios decline as the share increases, and the Gini coefficient falls accordingly. For example, when the share is 7%, inequality measures exceed their baseline levels, whereas when the share rises to 17%, they fall substantially below baseline.

Poverty also declines as the share of high-human-capital workers increases. The poverty rate is higher than baseline when the share is low, but falls significantly as the share rises, reflecting both higher aggregate income and reduced wage dispersion.

Overall, these results highlight the central role of the supply of high-human-capital workers in determining the effectiveness of R&D subsidies. When this supply is sufficiently large, subsidies stimulate research activity, technological progress, and economic growth while improving distributional outcomes. When it is limited, the same policy can generate weak innovation responses and even adverse growth and distributional effects. These findings underscore that the effectiveness of R&D subsidies depends critically on the human capital composition of the economy.

4.2 Alternative Fiscal Policies to Promote Innovation

In this subsection, we explore whether alternative fiscal tools can foster innovation and private R&D. We look at three alternative fiscal neutral policies: a reduction in the marginal effective tax rate (METR) of investment, increases in graduate education spending, and changes to personal income tax rates.

4.2.1 Taxes on Investment, τ^I

We begin by analyzing reductions in taxes that lower the cost of business investment. Specifically, we consider changes in the investment tax rate τ^I —a proxy for the marginal effective tax rate (METR) on investment—calibrated to have a fiscal cost comparable to current R&D

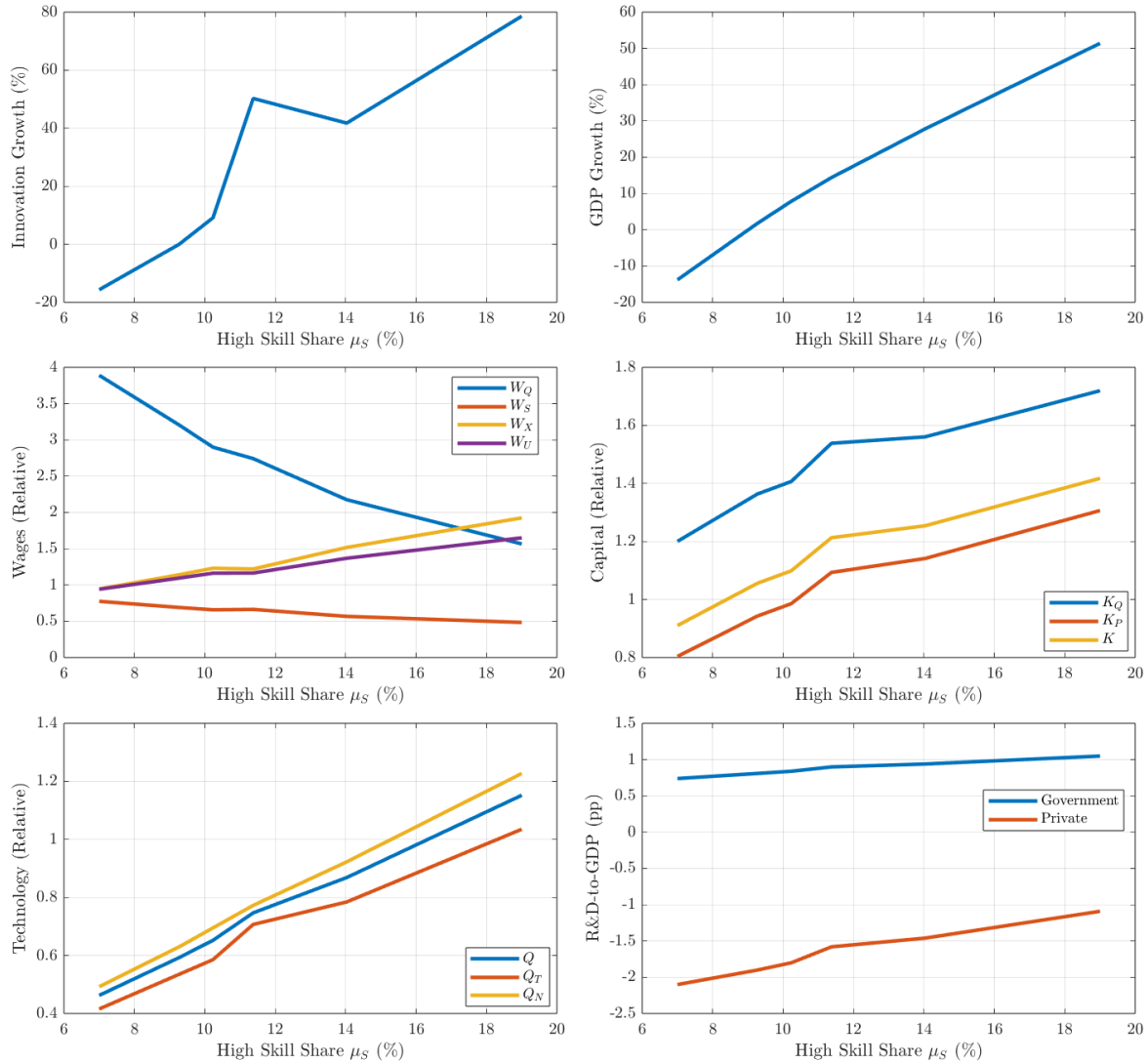


Figure 7: Effects of a 30.6% R&D Subsidy as a Function of the Population Share of High-Human Capital Workers. Panel (A) reports changes in innovation, GDP growth, private R&D, and the technology level. Panel (B) reports the allocation of capital between production and research. Panel (C) reports wage changes across worker types. Panel (D) plots the relationship between GDP growth and the Gini coefficient.

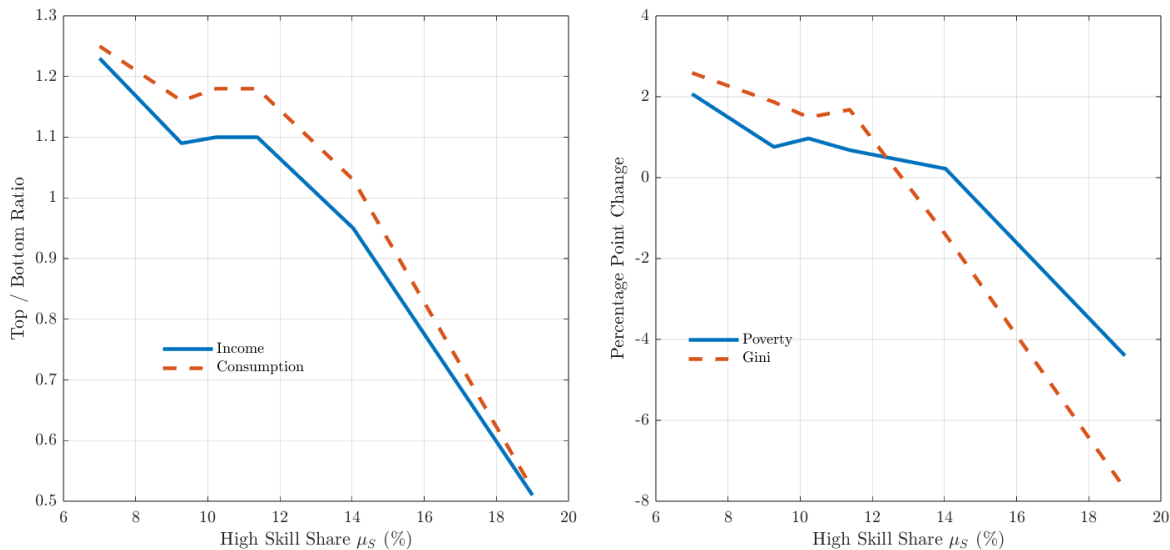


Figure 8: Distributional Effects of a 30.6% R&D Subsidy as a Function of the Population Share of High-Human Capital Workers. Panel (A) reports top-to-bottom decile ratios for income and consumption. Panel (B) reports percentage-point changes in the poverty rate and Gini coefficient.

subsidies.

Figure 9 compares the effects of reducing the METR on investment by 12.7 percentage points in an economy with fixed labor supply to those of R&D subsidies under both fixed and flexible labor supply. The figure also includes an increase in graduate education spending, discussed below. The reduction in τ^I increases innovation by 18% and GDP growth by 6.4%, corresponding to roughly 35% of the innovation effect and about 45% of the GDP growth effect generated by R&D subsidies under flexible labor supply.

A key advantage of lowering investment taxes is that, unlike generous R&D subsidies, it generates positive effects even when the supply of high-human-capital workers is inelastic. Under binding talent constraints, the growth effect of reducing τ^I is about 20 percentage points larger than that of R&D subsidies under fixed labor supply (-13.8%).

The difference in impact reflects distinct transmission mechanisms. Lower investment taxes promote capital deepening, expanding productive capacity. Given an elasticity of substitution greater than one between capital and low- and mid-human-capital labor, additional capital substitutes for these workers in production.

Initially, this substitution reduces wages for low- and mid-human-capital workers. Competition effects also lower wages for high-human-capital workers in production and research, which reduces firms' effective R&D costs and stimulates innovation. In general equilibrium,

however, higher investment and innovation increase labor demand, so wages for all worker types ultimately rise above baseline levels.

Figure 10 presents the distributional comparison. At the Canadian subsidy rate, reductions in investment taxes increase inequality, but less than R&D subsidies under flexible labor supply. The primary beneficiaries are households with large holdings of financial assets, including many high-human-capital households as well as lower-skill households that experienced favorable idiosyncratic shocks. Unlike R&D subsidies, which primarily benefit scientific labor, investment tax reductions benefit owners of physical capital and technology, leading to gains that are more broadly distributed, albeit still concentrated at the top.

The effects on poverty differ more markedly. Investment tax reductions reduce poverty relative to the baseline, as higher investment raises wages across all worker types. Although aggregate gains are smaller than under R&D subsidies with flexible labor supply, income gains are more evenly distributed, and for low- and mid-human-capital workers they are of similar magnitude.

These results are consistent with empirical evidence showing that lower tax burdens on business investment and corporate income stimulate innovation and capital accumulation. Using Chinese firm-level data, Cai et al., 2018 find that reductions in effective corporate tax rates increase both the quantity and quality of innovation. Mukherjee et al., 2017 show that higher corporate taxes are associated with lower patenting and product innovation, while Mooij and Ederveen, 2008 document strong effects of taxation on investment. By lowering the user cost of capital, these policies indirectly support innovation by easing financing constraints and expanding productive capacity.

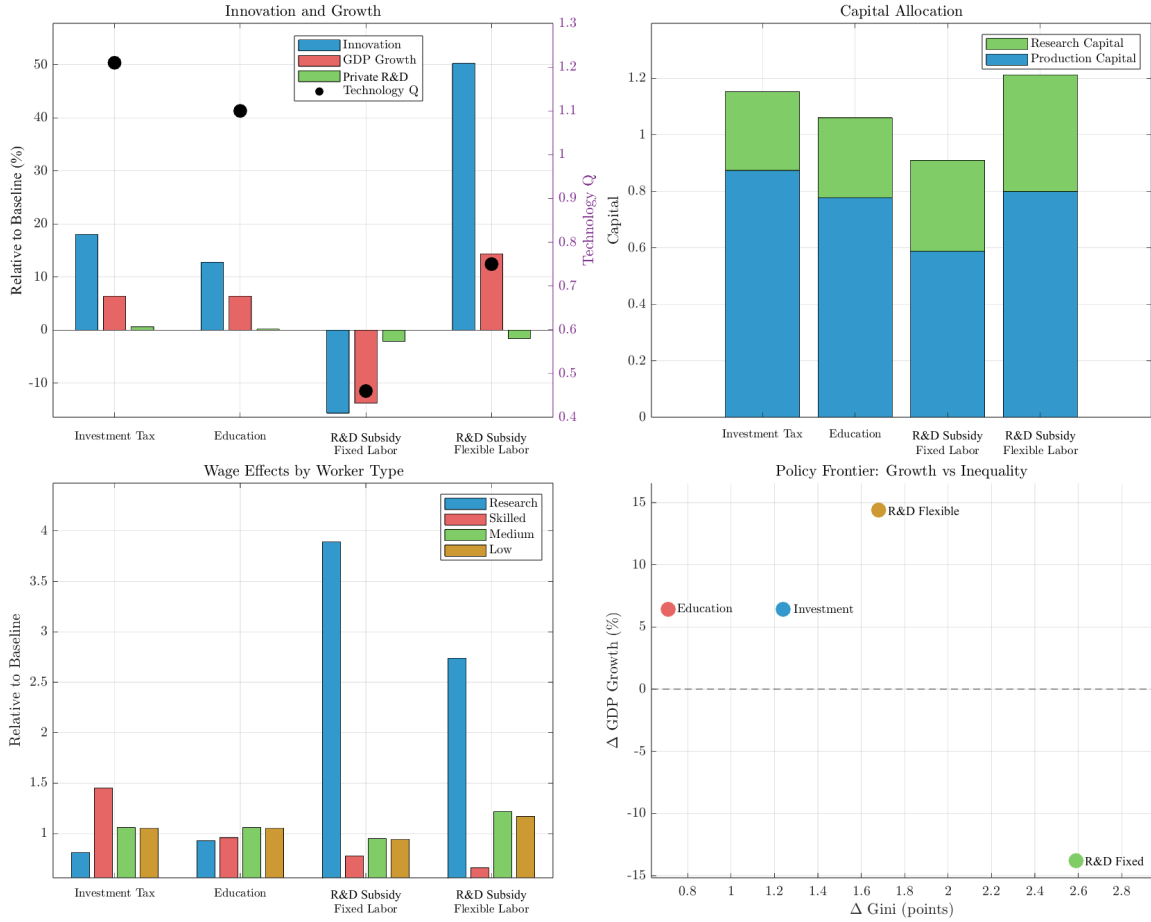


Figure 9: Comparison of four policy interventions: Investment Tax Reform, Graduate Education Spending Increase, and R&D Subsidies under Fixed and Flexible Labor Supply. All results are expressed relative to the zero-subsidy baseline of the economy with fixed population shares. Panel (A) reports changes in innovation, GDP growth, and private R&D relative to the baseline across the four policy interventions, together with the implied technology level Q . Panel (B) shows the allocation of capital between production and research activities. Panel (C) reports wage changes for research, high, medium, and low-human capital workers. Panel (D) plots the policy frontier by relating changes in GDP growth to changes in the Gini coefficient for each policy.

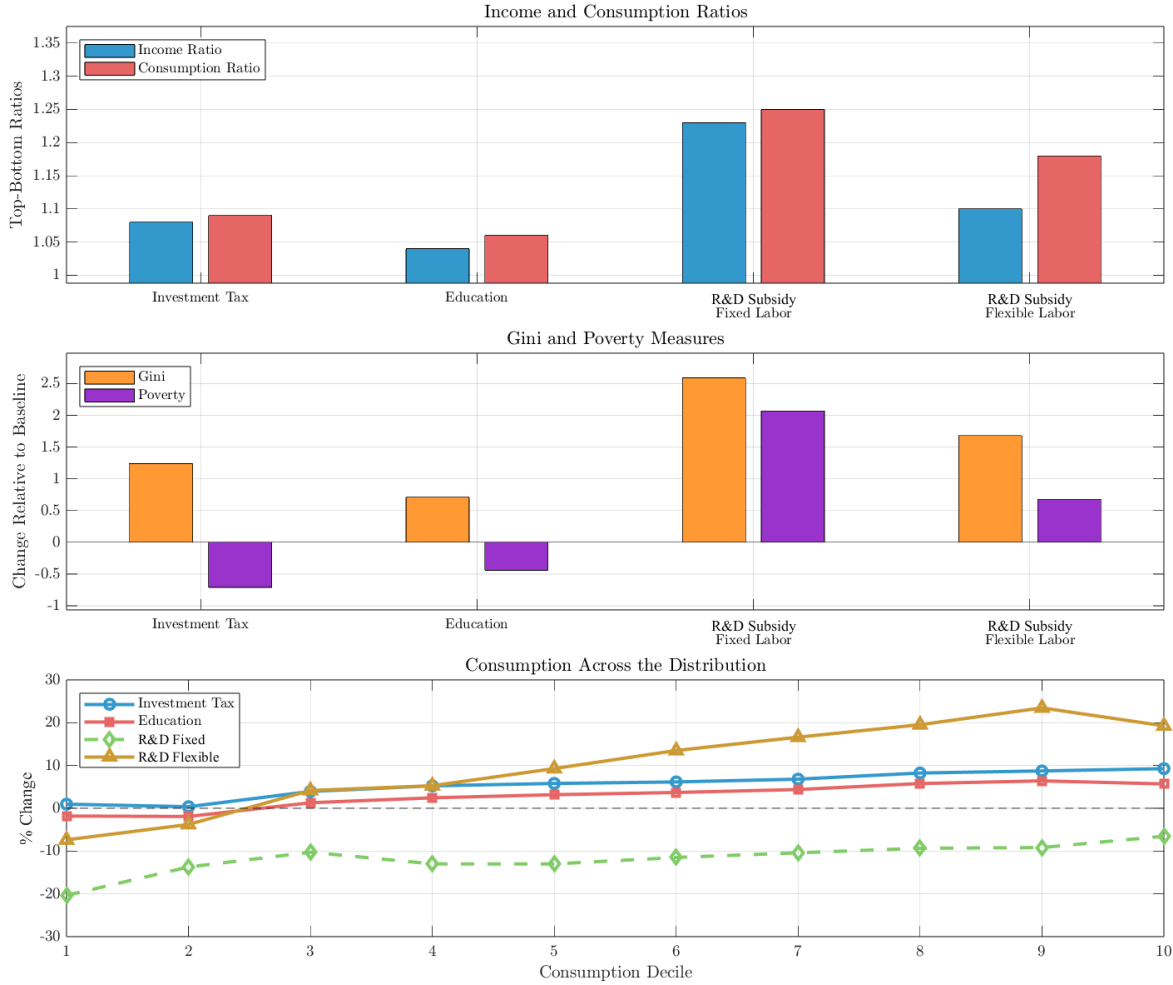


Figure 10: Distributional Effects of the four policy interventions: Investment Tax Reform, Graduate Education Spending Increase, and R&D subsidies under Fixed and Flexible Labor Supply. Panel (A) reports top-to-bottom ratios for income and consumption. Panel (B) reports changes in the Gini coefficient and the poverty rate relative to the baseline. Panel (C) shows percentage changes in consumption across deciles for each policy intervention.

Overall, these results suggest that, when labor supply is constrained, policies that promote general investment can stimulate innovation and growth more effectively than direct R&D subsidies, while also generating more evenly distributed income gains (see Figure 10).

4.2.2 Education Spending

The previous results highlight that the availability of research labor is a key determinant of innovation. Investment in post-tertiary education can expand this pool of workers. We

evaluate this policy in a cost-neutral manner relative to R&D expenditure.

The increase in education spending raises the share of high-human-capital workers by approximately 0.775 percentage points. This is based on the assumption that it takes four years of education to transition a worker from medium to high human capital, with an annual cost of roughly *CAN*\$60,000 per student, including living expenses.

As shown in Figure 9, this expansion increases innovation growth by 12.8 percent and long-run GDP by 6.4 percent. By directly relaxing the supply constraint on research labor, education spending generates durable gains in innovation without triggering large increases in scientists' wages. As a result, it achieves roughly 40% of the innovation gains from R&D subsidies, while delivering substantially smaller increases in inequality and reducing poverty (see Figure 10).

Among the policies considered, this approach yields the most favorable distributional outcomes. Its effectiveness is closely linked to the cost of education, suggesting that policies that reduce these costs could further amplify its impact.

These findings are consistent with cross-country evidence on the relationship between human capital and innovation. While Canada has a relatively high share of students in STEM fields (26.5% in 2022, above countries such as Switzerland, the United Kingdom, Japan, and the United States), the share of workers with advanced levels of education remains comparatively modest. Using Census-based educational attainment data for Canada and the United States, and consistently with our calibration, the share of high-human-capital workers—defined in the model as individuals with education beyond a bachelor's degree—is approximately 7% in Canada, compared to about 17% in the United States, implying a substantially smaller pool of research-oriented workers.

Broader measures of educational attainment point in a similar direction. According to OECD, 2024b data for 2023, Canada's share of tertiary-educated individuals (36.9%) is above the G7 average, but below that of leading innovation economies such as the United Kingdom and the United States (Figure 19). Evidence in Appendix C (Figures 18, 20, and 21) shows that countries with stronger innovation performance tend to exhibit higher levels of advanced and doctoral educational attainment.

Taken together, this evidence supports the central mechanism of the model: policies that expand the supply of high-human-capital workers—especially at advanced levels—can significantly enhance innovation capacity. In this context, education spending not only generates direct growth effects but also complements R&D subsidies by relaxing the talent constraints that limit their effectiveness.

More broadly, these complementarities between R&D subsidies and the size of the re-

search labor force may also help explain why innovation-oriented industrial policies tend to be more effective in economies with a larger supply of highly skilled labor. Relatedly, the results suggest that other policies aimed at expanding the effective supply of highly skilled labor could also complement R&D subsidies. In the Canadian context, this may include policies facilitating the immigration and retention of highly skilled workers and STEM graduates. While these channels are not explicitly modeled here, they would operate through mechanisms similar to those emphasized in the paper by relaxing talent constraints in research-oriented activities.

4.2.3 Personal Income Taxes

The economic literature emphasizes the role of personal income taxes in shaping incentives for human capital accumulation, entrepreneurship, and innovative activity. Lower taxes on labor income increase the returns to these activities and may therefore stimulate innovation.

To assess the quantitative importance of this channel in Canada, we consider a set of revenue-neutral policy experiments in which personal income taxes are reduced by an amount equivalent to the fiscal cost of the current R&D subsidy program. We compare a baseline economy—without R&D subsidies and with the current tax system—to otherwise identical economies with alternative PIT reductions.

Maintaining fiscal neutrality implies relatively small tax changes. We consider three scenarios targeting different parts of the income distribution: (i) a 1.15 percentage point reduction in the lowest federal bracket, primarily affecting the bottom 60% of the income distribution; (ii) a 1.5 percentage point reduction in the average tax rate for individuals with incomes above three times the median (roughly the top decile); and (iii) a 4.5 percentage point reduction in the average tax rate for individuals in the top 1%.

Figure 11 compares the effects of these PIT changes with those of an alternative reform that adopts the U.S. PIT schedule in Canada, as well as with direct R&D subsidies. The results suggest that changes in personal income taxes are less effective at stimulating innovation than direct R&D subsidies. Although high top-income tax rates may discourage the retention of highly skilled researchers—particularly in countries with significant international mobility of scientists, such as Canada (Akcigit et al., 2016)—the model simulations indicate relatively modest long-run effects on innovation, technology accumulation, and economic growth. For fiscal costs comparable to those of the current R&D subsidy program, the resulting changes in growth and innovation are generally below one percent.

These limited effects reflect both the relatively small tax adjustments required for fiscal neutrality and the indirect nature of the transmission mechanism. While lower income taxes

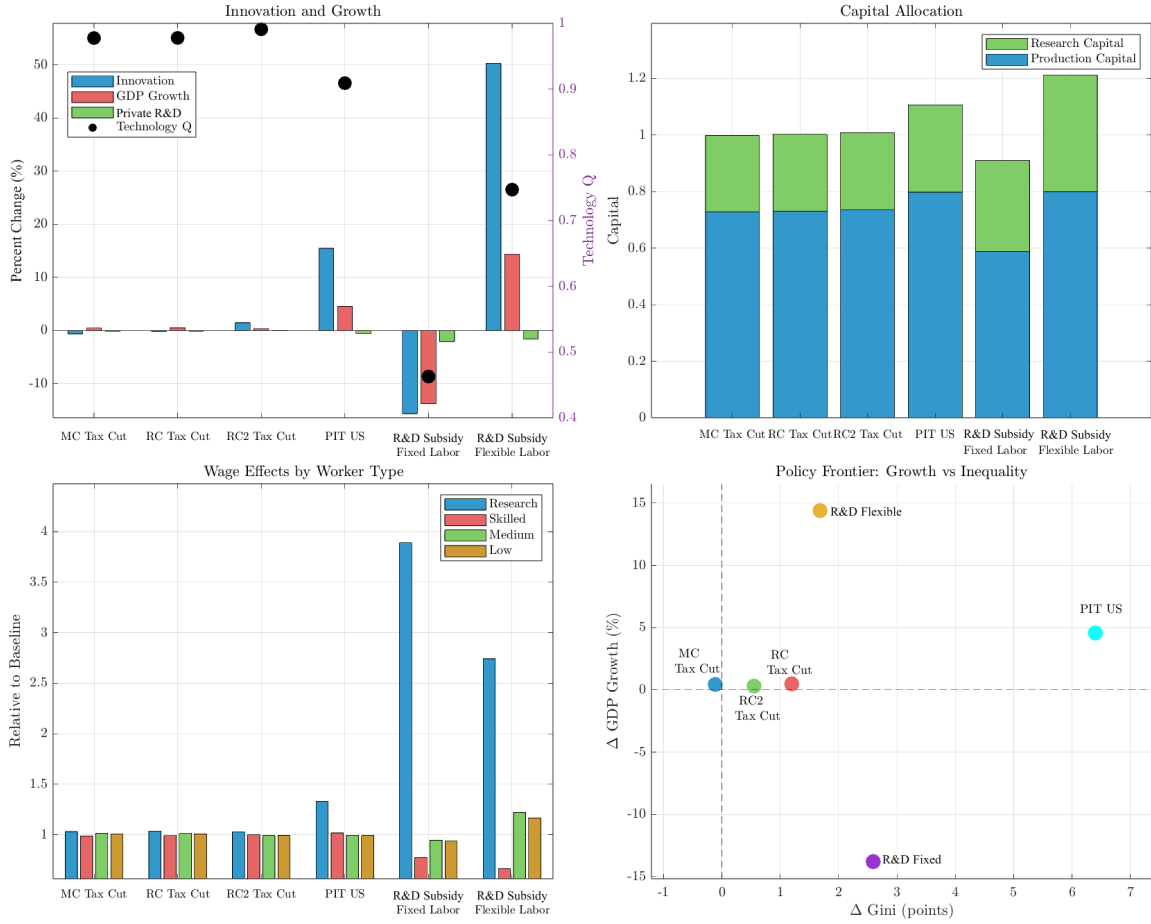


Figure 11: Comparison of six policy interventions: PIT cut for the Middle Class (MC), PIT cut for the Top 30% of the income distribution (RC), PIT cut for the Top 10% of the income distribution (RC2), PIT reform adopting the U.S. PIT schedule (PIT US), and R&D subsidies under fixed and flexible labor supply. All results are expressed relative to the zero-subsidy baseline with fixed population shares. Panel (A) reports changes in innovation, GDP growth, and private R&D, together with the implied technology level Q . Panel (B) shows the allocation of capital between production and research. Panel (C) reports wage changes for research, high-, medium-, and low-human-capital workers. Panel (D) plots the policy frontier relating changes in GDP growth to changes in the Gini coefficient.

improve incentives for human capital accumulation and research participation, these effects operate gradually and are not targeted specifically at innovative activity.

Larger tax reforms can generate more substantial effects. Appendix C (Figure 22) shows that while Canada’s federal PIT schedule is broadly comparable to those of other G7 countries, the inclusion of provincial taxes results in relatively high effective tax rates at upper income levels. For example, at income levels around 15 times the median, total marginal and average tax rates in Canada exceed those in the United States by approximately 9 and 12 percentage points, respectively.

Aligning Canada’s PIT schedule more closely with that of the United States would strengthen incentives for investment and innovation. The model suggests that such a reform could increase growth by 4.6% and innovation by 15.5%, exceeding the effects of more modest PIT changes. However, these gains come at a substantially higher fiscal cost—approximately 6.6 times that of the current R&D subsidy program—and remain smaller than those generated by targeted R&D subsidies.

The distributional implications differ from those of R&D subsidies. As shown in Figure 11, cost-neutral PIT reductions tend to generate relatively larger changes in inequality than in growth. In particular, closing the gap with the U.S. PIT schedule increases inequality proportionally more than it increases growth.

At the same time, Figure 12 shows that PIT reforms reduce poverty, in contrast to R&D subsidies. This reflects the fact that PIT reductions increase disposable income more broadly across the distribution, while R&D subsidies primarily raise wages in research occupations and have limited effects on wages in production. As a result, lower-income households benefit more directly from PIT reductions.

Overall, these findings suggest that, from a macroeconomic perspective, changes in personal income taxes are less effective than direct R&D subsidies as a policy instrument for promoting private R&D and fostering innovation.

One limitation of the analysis is that the model does not explicitly incorporate international labor mobility. As a result, it may not fully capture an important channel emphasized in the literature (e.g., Akcigit et al., 2016). That literature shows that superstar inventors’ location choices are sensitive to top income tax rates, with lower taxes attracting highly productive researchers across countries. By abstracting from this channel, the model may understate the potential effects of PIT reductions on innovation in open economies such as Canada.

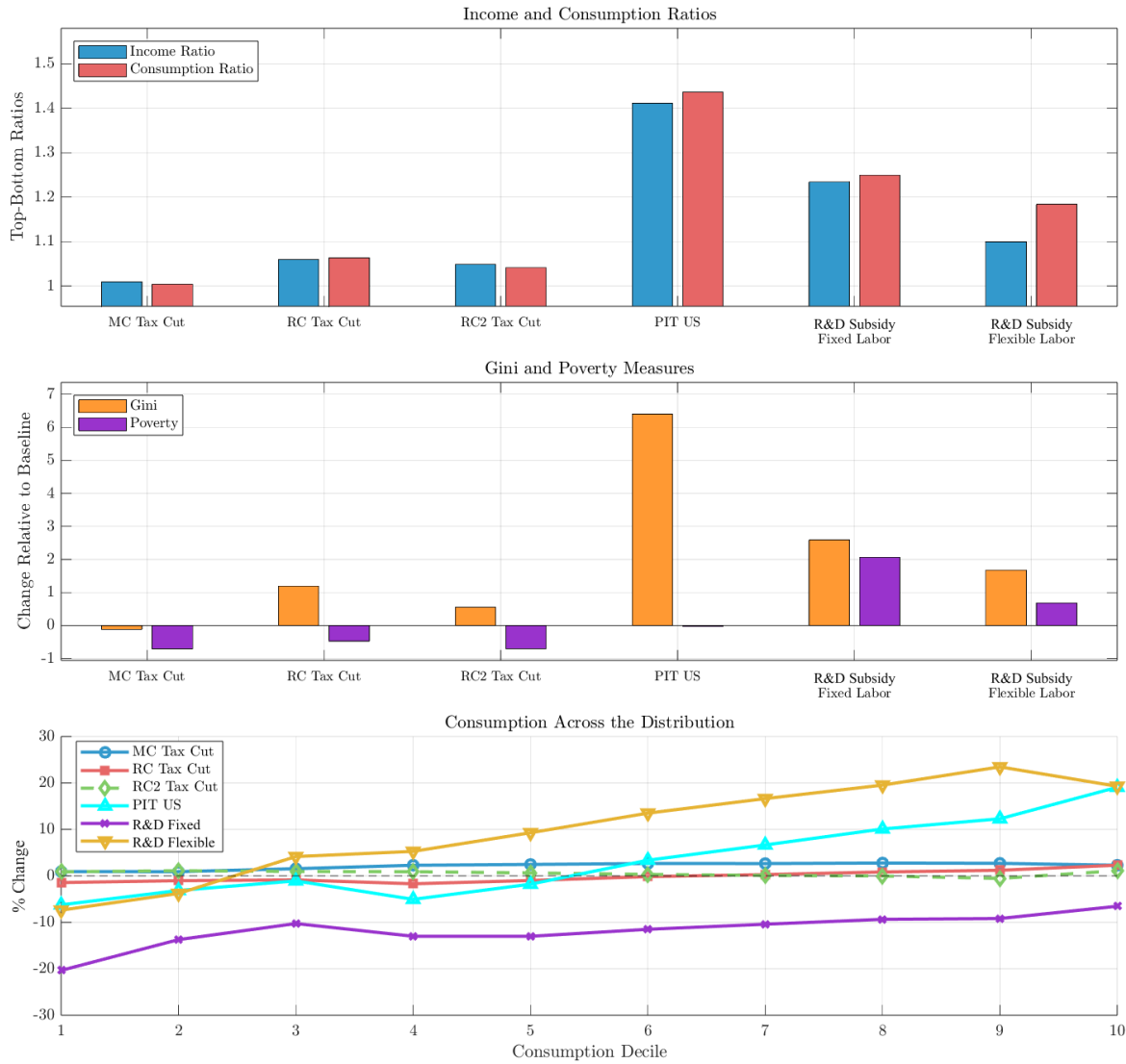


Figure 12: Distributional effects of the six policy interventions: PIT cut for the Middle Class (MC), PIT cut for the Top 30% (RC), PIT cut for the Top 10% (RC2), PIT reform adopting the U.S. schedule (PIT US), and R&D subsidies under fixed and flexible labor supply. Panel (A) reports top-to-bottom ratios for income and consumption. Panel (B) reports changes in the Gini coefficient and the poverty rate. Panel (C) shows percentage changes in consumption across deciles.

5 Conclusion

This paper evaluates the effectiveness of R&D subsidies as a policy tool to promote innovation and long-run economic growth, emphasizing the role of labor market constraints and distributional effects. The results highlight that R&D subsidies can be a powerful instrument: when the supply of high-human-capital labor is sufficiently elastic, subsidies generate large increases in innovation, technology accumulation, and output growth, exceeding the impact of alternative fiscal policies considered in this paper.

However, these gains are not unconditional. A central finding is that the effectiveness of R&D subsidies is critically constrained by the availability of research labor. When the supply of scientists is inelastic, subsidies primarily bid up wages rather than expanding innovative activity, leading to crowding out of private R&D and, in extreme cases, reductions in growth. This mechanism underscores that innovation policy cannot be evaluated in isolation from the underlying structure of the labor market.

The analysis also reveals important distributional trade-offs. R&D subsidies tend to increase inequality by disproportionately benefiting high-income individuals employed in research occupations. When labor supply is constrained, they may also increase poverty by reducing aggregate output and shifting the income distribution downward. While these adverse effects are mitigated when labor supply is more elastic, they remain an important consideration for policy design.

Other policies can also foster innovation and growth, though through different channels and with distinct trade-offs. Reductions in taxes on investment promote capital deepening and generate positive effects even in the presence of talent constraints, while also producing more broadly distributed income gains. Similarly, increased spending on higher education expands the supply of high-human-capital workers, easing the bottlenecks that limit the effectiveness of R&D subsidies and improving both growth and distributional outcomes. Although these policies are generally less powerful than R&D subsidies in terms of peak innovation effects, they tend to deliver more robust gains across different economic environments.

By contrast, changes in personal income taxation appear to have relatively modest effects on innovation and growth in this framework, particularly when constrained by fiscal neutrality. Although lower income taxes can improve incentives for human capital accumulation and entrepreneurial activity, their quantitative impact is small compared to more targeted policies such as R&D subsidies or investment tax reductions.

Overall, the results suggest that the most effective innovation strategy is not to rely on

a single policy instrument, but to combine R&D subsidies with measures that expand the supply of high-human-capital workers and reduce distortions to investment. In particular, policies that alleviate talent constraints—such as education investments—can substantially enhance the effectiveness of R&D subsidies while mitigating their adverse distributional consequences. This highlights the importance of a coordinated policy approach in which innovation policy and human capital policy are jointly designed.

More broadly, the results relate to the growing literature on industrial policy, which emphasizes complementarities between targeted policy interventions and broader structural conditions. In the context of this paper, the effectiveness of innovation-focused industrial policies is likely to depend not only on subsidy design, but also on the availability of complementary inputs such as highly skilled labor.

An interesting avenue for future research would be to explore more explicitly the role of sectoral targeting and asymmetric knowledge spillovers across industries. Another promising extension would be to study how advances in artificial intelligence may alter the complementarity between research capital and scientific labor, potentially relaxing some of the talent constraints emphasized in this paper.

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Appendices

A. Canada’s Innovation Performance and Policy Context

This appendix provides additional background on Canada’s innovation performance and policy framework.

Canada ranks among the top economies in global measures of innovation, including the Global Innovation Index (GII), but its position has remained broadly stable over the past decade, with limited upward momentum (Figure 13). At the same time, Canada performs strongly in several innovation inputs, including scientific publications per capita in engineering fields (Figure 14) and human capital formation.

Global Innovation Index Ranking, 2011-2024

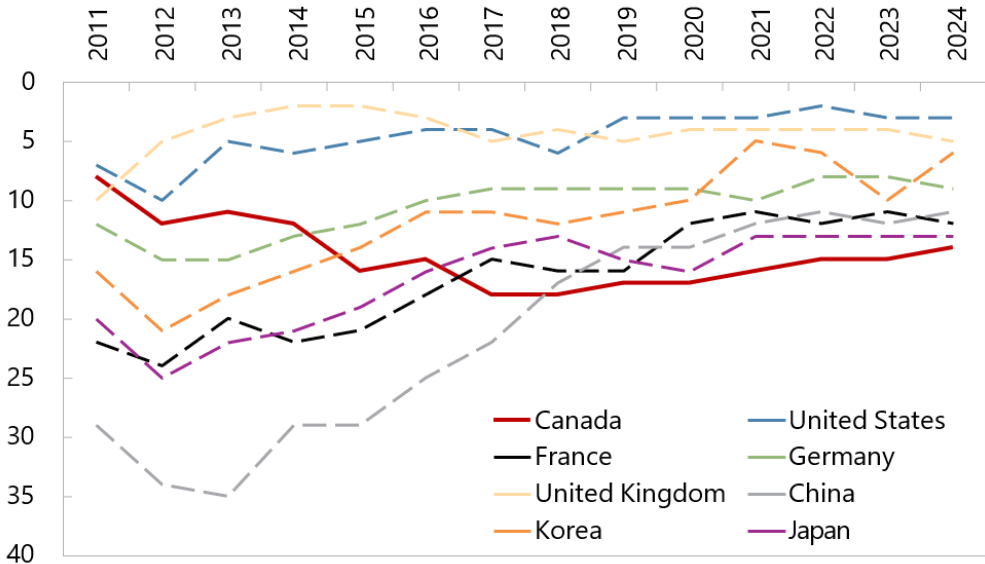


Figure 13: Global Innovation Index Ranking, 2011-2024. G7 countries plus the two top-15 countries in 2024 with the largest ranking improvements over the period.

Source: World Intellectual Property Organization

Despite these strengths, innovation outcomes have been more modest. Business expenditure on research and development (R&D) remains below that of leading innovators (Figure 15), particularly in sectors where innovation activity is typically concentrated.

Canada also provides among the most generous fiscal incentives for R&D among ad-

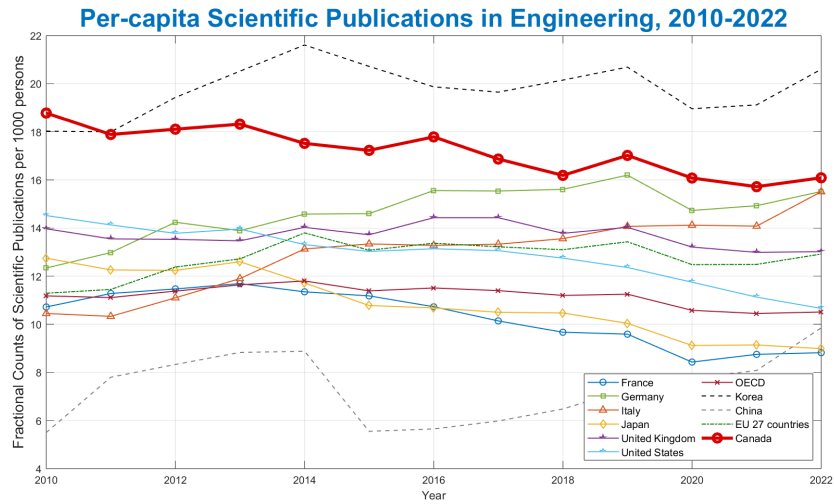


Figure 14: Scientific Publications in Engineering Fields, per capita, OECD, 2024c countries 2010-2022. Fractional counts per 1,000 persons.

Source: OECD, 2024c calculations based on Elsevier Scopus bibliometric data; author's calculations.

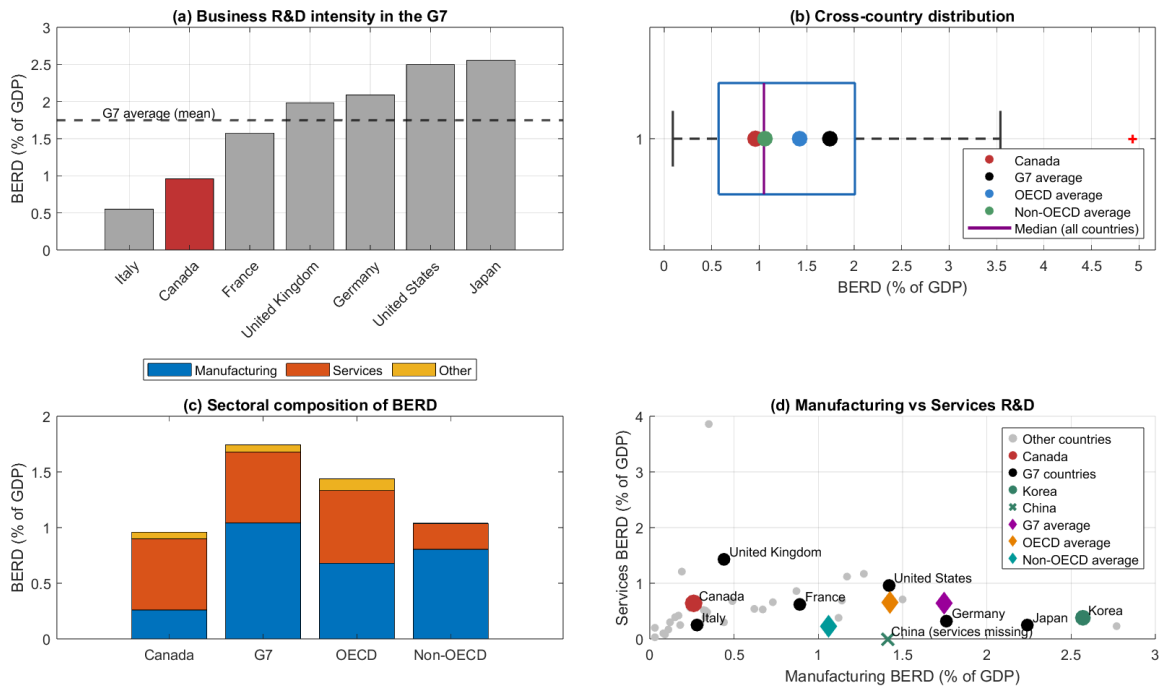


Figure 15: Business R&D intensity across countries (2018–2022 average, % of GDP).

Source: OECD, 2024a, Analytical Business Enterprise R&D (ANBERD) database; author's calculations using IMF GDP data.

vanced economies. Implied tax subsidy rates are high relative to G7 and OECD averages (Table 1). However, cross-country evidence suggests that higher tax support is not systematically associated with stronger innovation performance (Figure 16).

Table 1: **Implied Tax Subsidy Rates on R&D Expenditures 2023**

	Successful Scenario		Loss Making Scenario	
	SMEs	Large Firms	SMEs	Large Firms
Canada	31.0%	13.0%	31.0%	10.0%
Innovators ^a	18.2%	14.1%	16.4%	12.0%
G7 average	19.7%	16.7%	16.6%	12.4%
France	36.0%	36.0%	36.0%	29.0%
Germany	21.0%	21.0%	20.0%	20.0%
Italy	9.0%	9.0%	9.0%	9.0%
Japan	20.0%	17.0%	-1.0%	-1.0%
United Kingdom	18.0%	18.0%	18.0%	18.0%
United States of America	3.0%	3.0%	3.0%	2.0%
OECD average	18.0%	15.0%	16.0%	13.0%
EU-27 average	16.0%	16.0%	14.0%	13.0%
Sample average ^b	17.2%	15.2%	13.6%	11.4%

^a Top innovators correspond to economies in the full sample in the top 15 in terms of innovation in 2022 according to the Global Innovation Index produced by the World Intellectual Property Organization.

^b Countries in the full sample average include: AMs - Austria, Australia, Belgium, Canada, Croatia, Cyprus, Czechia, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Korea, Japan, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States. EMs - Argentina, Brazil, Chile, China, Colombia, Costa Rica, Hungary, Mexico, Peru, Romania, Russia, South Africa, Turkey, Thailand.

Source: *INNOTAX - OECD, 2023*

From an institutional perspective, Canada relies heavily on tax-based support for innovation, particularly through the Scientific Research and Experimental Development (SR&ED) program. This approach has been complemented by targeted programs in recent years, including support for clean technology, advanced manufacturing, and digital industries.

International comparisons indicate that countries with stronger improvements in innovation performance often combine fiscal incentives with more targeted industrial strategies and greater alignment between public funding and priority sectors (e.g. Table 2 compares the innovation ecosystem of Canada to that of four countries with strong innovation outcomes). In contrast, Canada’s policy framework remains relatively broad-based.

Taken together, these patterns suggest that constraints beyond financial incentives—particularly

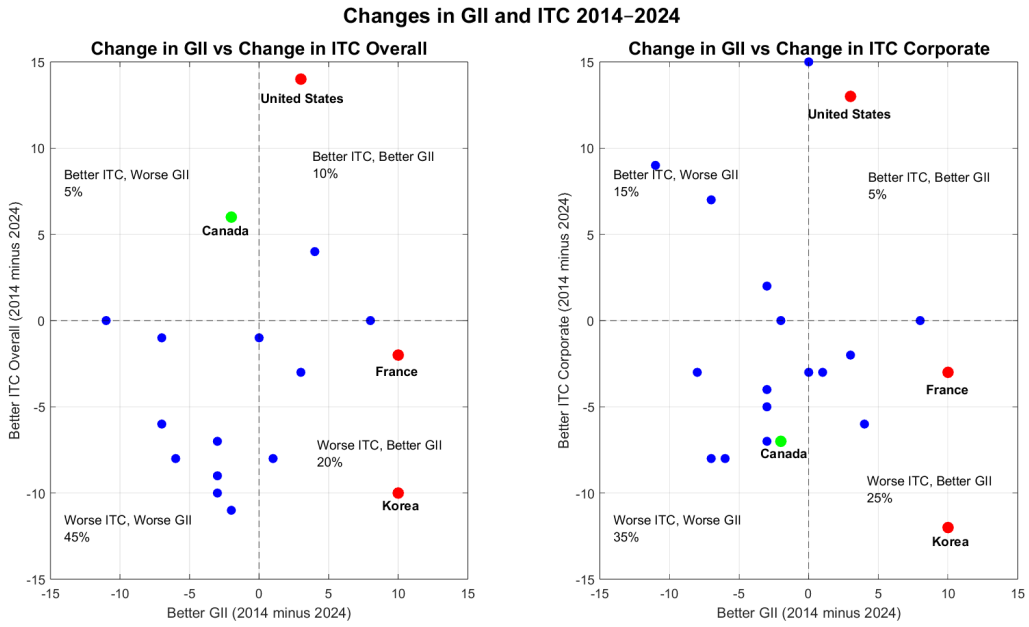


Figure 16: Changes in the Global Innovation Index (GII) versus changes in the International Tax Competitiveness Index (ITC), 2014–2024. The figure shows two panels: the left panel reports changes in the overall tax system, while the right panel focuses on corporate income taxation.

Source: World Intellectual Property Organization, 2011–2024 and Tax Foundation, 2014–2024.

Table 2: Comparative Overview of Innovation Ecosystems in 2025: Canada, France, South Korea, and China

Dimension	Canada	France	South Korea	China
Innovation ranking	17th (2025); decline of 3 places over decade; strong publications per capita; moderate foreign patenting	13th (2025); gain of 5 places; strong AI and deep tech; high foreign patenting	4th (2025); gain of 8 places; strong patenting; high R&D intensity	10th (2025); gain of 19 places; global leader in patent filings; rapid gains in AI and manufacturing
Public R&D support	SR&ED; IRAP; SD Tech Fund; Mitacs	CIR; PIA funding; Bpifrance initiatives; AI support	R&D tax credits; funding for strategic sectors	State-led R&D programs; Five-Year Plans; funding for AI, semiconductors, green tech
Private funding	Venture Capital ecosystem growing but modest; limited angel networks	Expanding Venture Capital ecosystem; Station F (1,000+ startups); strong AI funding	Strong Venture Capital ecosystem; conglomerate co-investment	Large domestic Venture Capital market; strong corporate investment
Startup ecosystem	Toronto, Montreal, Vancouver; moderate scale-up activity	Paris, Lyon, and regional hubs; deep tech clusters	Seoul, Busan, Daegu; dense tech ecosystem	Beijing, Shenzhen, Shanghai, Hangzhou; rapid scaling hubs
Strategic sectors	Clean tech, digital technologies, life sciences	Clean tech, AI, biotech; some defense	Semiconductors, AI, biotech, green technology	AI, semiconductors, advanced manufacturing, green energy, biotech
Challenges	Skilled labor constraints; uneven diffusion; regulatory complexity	Labor constraints; regulatory hurdles; scaling issues	Skill shortages; intense competition; reliance on conglomerates	Geopolitical tensions; export controls; uneven IP protection

Notes: SR&ED = Scientific Research and Experimental Development tax credit; IRAP = Industrial Research Assistance Program; SD Tech Fund = Sustainable Development Technology Fund; Mitacs = university–industry research collaborations; CIR = Crédit Impôt Recherche; PIA = Programmes d’Investissements d’Avenir; Bpifrance = public investment bank; Station F = Paris-based startup campus hosting 1,000+ startups.

the availability of high-skilled labor—may limit the effectiveness of innovation policy.

B. Calibration Details

The model is solved numerically for a stationary recursive equilibrium. Households' dynamic optimization problems are solved using value function iteration, taking prices as given. The stationary distribution of households is obtained as the invariant distribution induced by optimal policy functions and the stochastic process for idiosyncratic productivity.

The stationary equilibrium of the model is calibrated to match key features of the Canadian economy related to aggregate demand, sectoral composition, skill distribution, research and development intensity, consumption patterns, and the distribution of market income. Unless otherwise stated, calibration targets are based on averages over the period 2000Q1–2025Q1 or on the most recent available Census and OECD data. The calibration proceeds in three blocks: production and technology, household behavior and income distribution, and government policy. Each block targets a set of empirical moments, while key parameters are jointly determined to match cross-sectional and aggregate features of the data.

B.1 Production Functions

B.1.1 Goods and Services Production

The production side of the economy is divided into three sectors: (i) tradable goods (agriculture, manufacturing, mining), (ii) low-technology services, and (iii) high-technology services.

Empirical evidence points to stronger complementarity between capital and skilled labor and greater substitutability between capital and unskilled labor. We capture these features using nested CES production functions that allow for differential substitution patterns across inputs.

Functional Forms. Production combines sector-specific technology and a composite of non-technology inputs. Tradable goods and high-technology services use capital, multiple types of labor, and intermediate inputs, while low-technology services use only labor. Full functional forms are reported below.

Tradable Goods:

$$\begin{aligned}
Y_t^{T1} &= \left(\bar{A}^{T1} \Theta_t^\zeta \right) (Q_t^{T1})^{1-\alpha^{F,T1}} \\
&\quad \times \left[F^{T1} \left(K_t^{P,T1}, H_t^{U,T1}, H_t^{X,T1}, H_t^{S,T1}, M_t^{T,T}, M_t^{N2,T} \right) \right]^{\alpha^{F,T1}} \\
F^{T1} \left(K^{P,T1}, H^{U,T1}, H^{X,T1}, H^{S,T1}, M^{T1,T1}, M^{N2,T1} \right) &= \left[\Upsilon^{KXU} \left(K^{P,T1}, \Upsilon^{XU} \left(H^{X,T1}, H^{U,T1} \right) \right) \right]^{\alpha^{KXU,T1}} \\
&\quad \times \left[\Upsilon^{mm} \left(M^{T1,T1}, M^{N2,T1} \right) \right]^{\alpha^{mm,T1}} \\
&\quad \times \left(H^{S,T1} \right)^{1-\alpha^{KXU,T1}-\alpha^{mm,T1}} \\
\Upsilon^{KXU} \left(K^{P,T1}, \Upsilon^{XU} \left(H^{X,T1}, H^{U,T1} \right) \right) &= \left[\gamma^{T1} \left(K^{P,T1} \right)^{\chi^{T1}} + \left(1 - \gamma^{T1} \right) \left(\Upsilon^{XU} \left(H^{X,T1}, H^{U,T1} \right) \right)^{\chi^{T1}} \right]^{\frac{1}{\chi^{T1}}} \\
\Upsilon^{XU} \left(H^{X,T1}, H^{U,T1} \right) &= \left[\iota^{T1} \left(H^{X,T1} \right)^{\varphi^{T1}} + \left(1 - \iota^{T1} \right) \left(H^{U,T1} \right)^{\varphi^{T1}} \right]^{\frac{1}{\varphi^{T1}}} \\
\Upsilon^{mm} \left(M^{T1,T1}, M^{N2,T1} \right) &= \left[\xi^{T1} \left(M^{T1,T1} \right)^{\eta^{T1}} + \left(1 - \xi^{T1} \right) \left(M^{N2,T1} \right)^{\eta^{T1}} \right]^{\frac{1}{\eta^{T1}}}.
\end{aligned}$$

Low-Technology Services:

$$\begin{aligned}
Y_t^{N1} &= \left(\bar{A}^{N1} \Theta_t^\zeta \right) \left[F^{N1} \left(H_t^{U,N1}, H_t^{X,N1} \right) \right] \\
F^{N1} \left(H^{U,N1}, H^{X,N1} \right) &= \left[\kappa^{N1} \left(H^{X,N1} \right)^{\epsilon^{N1}} + \left(1 - \kappa^{N1} \right) \left(H^{U,N1} \right)^{\epsilon^{N1}} \right]^{\frac{1}{\epsilon^{N1}}}.
\end{aligned}$$

High-Technology Services

$$\begin{aligned}
Y_t^{N2} &= \left(\bar{A}^{N2} \Theta_t^\zeta \right) (Q_t^{N2})^{1-\alpha^{F,N2}} \\
&\quad \times \left[F^{N2} \left(K_t^{P,N2}, H_t^{X,N2}, H_t^{S,N2}, M_t^{T1,N2}, M_t^{N2,N2} \right) \right]^{\alpha^{F,N2}} \\
F^{N2} \left(K^{P,N2}, H^{X,N2}, H^{S,N2}, M^{T1,N2}, M^{N2,N2} \right) &= \left[\Omega^{KX} \left(K^{P,N2}, H^{X,N2} \right) \right]^{\alpha^{KX,N2}} \\
&\quad \times \left[\Omega^{mm} \left(M^{T1,N2}, M^{N2,N2} \right) \right]^{\alpha^{mm,N2}} \\
&\quad \times \left(H^{S,N2} \right)^{1-\alpha^{KX,N2}-\alpha^{mm,N2}} \\
\Omega^{KX} \left(K^{P,N2}, H^{X,N2} \right) &= \left[\lambda^{N2} \left(K^{P,N2} \right)^{\psi^{N2}} + \left(1 - \lambda^{N2} \right) \left(H^{X,N2} \right)^{\psi^{N2}} \right]^{\frac{1}{\psi^{N2}}}, \\
\Omega^{mm} \left(M^{T1,N2}, M^{N2,N2} \right) &= \left[\zeta^{N2} \left(M^{T1,N2} \right)^{\vartheta^{N2}} + \left(1 - \zeta^{N2} \right) \left(M^{N2,N2} \right)^{\vartheta^{N2}} \right]^{\frac{1}{\vartheta^{N2}}}.
\end{aligned}$$

Factor Shares and Input Intensities. Factor shares are calibrated using Canadian Supply and Use Tables (2021). Table 3 reports the distribution of intermediate inputs, labor, and

capital across sectors. Consistent with the data, tradable goods are the most capital-intensive sector, while services are more labor-intensive. Low-technology services are assumed to use only labor, reflecting their limited reliance on specialized capital.

Table 3: Share of Income per Factor
(%) for Non-Technology Inputs

	Goods	Low- Technology Services	High- Technology Services
Intermediate Goods and Services to Output	57	45	38
Intermediate Goods to Output	17	3	1
Intermediate Services to Output	39	43	37
Labor to Value Added	46	68	71
Capital to Value Added	54	30	29

Source: Statistics Canada, 2021. Supply and Use Tables at purchaser prices, 2021, expressed in 2017 constant prices.

Technology Shares. We measure the role of technology using data on R&D and software expenditures from Supply and Use Tables, complemented by estimates of intangible capital (Baldwin et al., 2008). Table 4 reports sectoral technology intensities.

Measured technology use is minimal in low-technology services. To avoid understating the aggregate importance of technology, we set its contribution to zero in that sector and reallocate its measured share proportionally across the remaining sectors. This yields calibrated technology shares of 8 percent in tradable goods and 10 percent in high-technology services.

Table 4: Technology Factor Share of Value Added by Sector (%)

	Goods	Low- Technology Services	High- Technology Services
R&D + Software Expenses to Value Added	1	1	10
Intangible Capital to Value Added	11	6	6
Average Technology Share	6	4	8
Model Calibration ¹	8	0	10

¹/1 No technology intensity in the low-technology sector; technology participation in low-technology is evenly reallocated among the other sectors.

Source: Supply and Use Tables at purchaser prices 2021, Statistics Canada, 2021; Baldwin, Gu, Macdonald (2008); Author Estimates.

Sectoral and Expenditure Shares. Sectoral shares of GDP and expenditure components are additional calibration targets. The model closely matches the size of high-technology services and aggregate expenditure shares, while slightly overstating the goods sector and understating low-technology services. This reflects the model’s abstraction that all investment goods are tradable, which mechanically increases the measured size of the goods sector.

Table 5: Sectoral Shares of GDP (%)

	Data	Model
Goods	18.9	26.2
Low-Technology Services	45.0	38.5
High-Technology Services	36.1	35.3

1/ Includes agriculture, manufacturing, and mining.

2/ Includes accommodation and food services, administrative and waste management, arts and entertainment, construction, government services, real estate, retail and wholesale trade, utilities, and transportation.

3/ Includes education, finance and insurance, healthcare, and professional services.

Source: Statistics Canada, 2024c, Canadian System of National Accounts.

Table 6: Expenditure Shares of GDP

	Data	Model
Household Consumption	53.7	54.8
Government Spending	21.3	21.2
Private Investment	19.6	19.6

Source: Statistics Canada, 2024c, Canadian System of National Accounts.

Calibration Targets. In total, the production block is disciplined by 23 targets: intermediate input shares, labor and capital shares, technology shares, sectoral GDP shares, and expenditure shares.

These targets jointly determine the parameters of the production structure, reflecting the interdependence between input shares, sectoral composition, and technology use. The parameters are shown in Table 7. Substitution elasticities are chosen to satisfy two conditions: (i) higher substitutability between capital and low- and medium-skilled labor than with high-skilled labor, and (ii) equilibrium wage premia consistent with the data. Remaining elasticities are set within empirically plausible ranges and primarily affect second-order responses.

B.1.2 R&D Production Function

Factor Intensity. R&D investment combines capital and specialized labor. Consistent with evidence that most R&D expenditures correspond to labor costs, we set the capital share to $\varrho^{T1} = \varrho^{N2} = \varrho = 0.3$.

Employment and Investment Targets. The parameters governing R&D activity, A^Q and δ^Q , are calibrated to match both employment and investment moments.

Employment. A^Q is chosen to match the share of labor employed in R&D. According to Statistics Canada, 2024a, R&D personnel (researchers and support staff) represents ap-

Table 7: Technology Parameters
Benchmark values used in production sectors

Parameter	Value	Description / Notes
Tradable goods T1		
$\alpha_{KXU,T1}$	0.40	Capital/Medium-skilled-labor share
$\alpha_{mm,T1}$	0.38	Intermediate composite share
$\alpha_{S,T1}$	0.14	High-skilled-labor composite share
$1 - \alpha_{F,T1}$	0.08	Technology share
γ^{T1}	0.55	Capital share in composite capital labor, manufacturing
χ^{T1}	0.3	Substitutability of capital and labor= $\frac{1}{1-\chi^{T1}}$ labor, manufacturing
ι^{T1}	0.595	Medium-skilled-labor share of composite labor
φ^{T1}	0.15	Substitutability of medium- and low-skilled labor= $\frac{1}{1-\varphi^{T1}}$
ξ^{T1}	0.30	Tradable intermediate share
η^{T1}	0.2	Substitutability of tradable vs non-tradable intermediates= $\frac{1}{1-\eta^{T1}}$
Low-technology services N1		
κ^{N1}	0.745	Medium-skilled-labor share
ϵ^{N1}	0.5	Substitutability of medium- and low-skilled labor= $\frac{1}{1-\epsilon^{N1}}$
High-technology services N2		
$\alpha_{KX,N2}$	0.37	Capital/Medium-skilled-labor share
$\alpha_{mm,N2}$	0.33	Intermediate composite share
$\alpha_{S,N2}$	0.20	High-skilled-labor composite share
$1 - \alpha_{F,N2}$	0.10	Technology share
λ^{N2}	0.4	Capital share in composite capital medium-skilled labor
ψ^{N2}	0.3	Substitutability of capital= $\frac{1}{1-\psi^{N2}}$ medium-skilled labor
ζ^{N2}	0.10	Tradable intermediate share
ϑ^{N2}	0.2	Substitutability of tradable vs non-tradable intermediates= $\frac{1}{1-\vartheta^{N2}}$
δ^K	0.055	Depreciation of capital used in goods and services production

proximately 1.52 percent of total employment. In the model, this moment is interpreted as capturing the size of the research-oriented labor force in the economy, implying $A^Q = 5.45$.

Investment. δ^Q is chosen to match the relative size of investment in innovative property. Combining national accounts data on tangible capital with estimates of intangible capital (Baldwin et al., 2012), we find that investment in innovative property corresponds to approximately 20 percent of tangible investment. This moment implies $\delta^Q = 0.0675$.

Model Fit. In the data, private R&D expenditure averages 1.3 percent of GDP and public R&D 0.6 percent. The model matches public R&D closely and slightly overstates private R&D intensity. This reflects the absence of financial frictions and firm heterogeneity in the model, which tend to dampen R&D investment in the data.

Table 8: Technology Parameters – R&D Production Function

Parameter	Value	Description / Notes
ϱ^{T1}	0.3	Capital share of investment in R&D, T1
ϱ^{N2}	0.3	Capital share of investment in R&D, N2
A^Q	5.45	Research productivity, T1 & N2
δ^Q	0.0675	Depreciation of the technology stock, T1 & N2

Source: Statistics Canada, [2024b](#), *Industrial research and development*, 2022 (actual), 2023 (preliminary), and 2024 (intentions); *The Daily*, September 5, 2024.

Table 9: R&D Expenditures Share of GDP

	Data	Model
Private sector	1.3	2.4
Public sector	0.6	0.7

Source: OECD, [2024c](#) Main Science and Technology Indicators, average 2010–2022.

B.2 Preferences

Functional Forms. Households derive utility from consumption and leisure:

$$u(c, l) = \frac{1}{1 - \sigma} \left(c - \omega \frac{l^{\theta+1}}{\theta + 1} \right)^{1 - \sigma}.$$

Consumption is a composite good with a nested CES structure combining tradable goods and services, and further decomposed into domestically produced and imported goods, as well as low- and high-technology services.

$$\begin{aligned}
c &= \left[\gamma^c (c^T(c^{T1}, c^F))^{\rho^c} + (1 - \gamma^c) (c^N(c^{N1}, c^{N2}) + \bar{c}^N)^{\rho^c} \right]^{\frac{1}{\rho^c}}, \\
c^T &= \left[\gamma^T (c^{T1})^{\rho^T} + (1 - \gamma^T) (c^F)^{\rho^T} \right]^{\frac{1}{\rho^T}}, \\
c^N &= \left[\gamma^N (c^{N2})^{\rho^N} + (1 - \gamma^N) (c^{N1})^{\rho^N} \right]^{\frac{1}{\rho^N}}.
\end{aligned}$$

Utility Parameters. We set the coefficient of relative risk aversion to $\sigma = 2$. The discount factor β is chosen to match the capital–output ratio. The disutility of labor parameter ω follows Trabandt and Uhlig, 2011, consistent with average hours worked equal to one-third of available time. The Frisch elasticity parameter $\theta = 3$ implies a labor supply elasticity of approximately one-third.

Occupational Choice. For high-human-capital households, the parameter κ^{lS} governing the allocation of labor between production and research is calibrated to match the share of scientists among high-skilled workers. In the data, this ratio is approximately $0.214 = \frac{1.5\%}{7\%}$. We assume complementarity between occupations, reflecting limited substitutability between production and research tasks.

Consumption. We assume unit elasticity of substitution across consumption aggregates. Non-homotheticity is introduced through \bar{c}^N , following Lizarazo et al., 2017, to match the higher share of services in consumption among high-income households.

Consumption share parameters $(\gamma^c, \gamma^T, \gamma^N)$ are calibrated using Canadian Input–Output tables (2021) to match expenditure shares across goods and services. The model exactly reproduces these shares (Table 10).

Table 10: Consumption Shares of Consumption Expenditure

	Data	Model
Goods (domestically produced)	28	28
Goods (imported)	14	14
Low-technology services	16	16
High-technology services	42	42

Source: Statistics Canada, 2021, Input–Output final uses at purchaser prices, 2021, expressed in 2017 constant prices; author calculations.

Table 11: Preferences Parameters
Benchmark values used in Utility and Consumption Functions

Parameter	Value	Description / Notes
β	0.96	Discount factor
σ	2.0	Risk aversion
ω	12.0	Weight of labor in utility (Trabandt and Uhlig, 2014)
θ	3.0	Frisch elasticity of labor supply= $\frac{1}{\theta}$
κ^{lS}	0.5	Production vs research for high-skill employment
ρ^{lS}	-0.35	Substitutability of production and research occupations for high-skill labor= $\frac{1}{1-\rho^{lS}}$
γ^c	0.3825	Weight of tradable goods vs Services in consumption
ρ^c	0.01	Substitutability of tradable vs non-tradable goods= $\frac{1}{1-\rho^c}$
\bar{c}^N	0.05	Non-homothetic preference shifter in services
γ^T	0.665	Weight domestically produced goods vs imported goods
ρ^T	0.01	Substitutability of domestic vs imported goods= $\frac{1}{1-\rho^T}$
γ^N	0.275	Weight low-technology services vs high-technology
ρ^N	0.01	Substitutability of low-technology vs high-technology services= $\frac{1}{1-\rho^N}$

B.3 Skill Distribution

The population is divided into three human capital groups based on educational attainment: low (no post-secondary), medium (some post-secondary or bachelor’s degree), and high (master’s or doctorate). Population shares are calibrated using educational attainment categories from the 2021 Census and are closely matched in the model (Table 12). The calibration is intended to capture broad differences in the aggregate supply of advanced human capital relevant for research-oriented activities, rather than specific occupational, age, or professional-degree classifications. Cross-country comparisons use harmonized Census-based educational attainment categories consistent with this definition.

Table 12: Population Shares by Human Capital Group
 (%)

	Data	Model
Low skill	42.8	43.0
Medium skill	50.5	50.0
High skill	6.7	7.0

Source: Statistics Canada, 2023, Census Profile, 2021 Census of Population; author calculations.

Household labor productivity consists of a permanent component ν^j and an idiosyncratic stochastic component. The permanent component is calibrated to match wage premia across education groups. Normalizing $\nu^X = 1$, we set $\nu^U = 0.7$ and $\nu^S = 1.15$, reflecting differences in years of education and associated earnings premia.

Table 13: Permanent Labor Efficiency Parameters

Parameter	Value	Description / Notes
ν^U	0.7	target $w^x > w^U$
ν^X	1.0	Baseline
ν^S	1.15	target w^S & $w^Q > w^X$

B.4 Income Distribution

The model is calibrated to reproduce the distribution of market income across deciles using Census 2021 data. Income is expressed relative to median income.

In addition to permanent productivity differences, idiosyncratic productivity shocks are introduced to match the observed income distribution. These shocks follow group-specific three-state Markov processes characterized by persistence ρ^j and variance $\sigma_{\varepsilon,j}^2$.

The parameters governing these processes are chosen to minimize the distance between the model-implied distribution and the empirical Lorenz curve for pre-tax income.

The model captures well the overall dispersion and shape of the income distribution, although it slightly understates income at the bottom and overstates concentration at the top.

B.5 Government

This section provides a detailed description of the calibration of fiscal policy instruments, which play a central role in the model. We calibrate government expenditures and revenues to match key features of the Canadian fiscal system. Table 16 summarizes the parameter values.

Public Consumption. Public consumption is defined as

$$G = G^{T1} + p^{N1}G^{N1} + p^{N2}G^{N2}.$$

It is calibrated to match its share of GDP. The composition across sectors is chosen to be consistent with sectoral output shares: G^{N1} and G^{N2} are set to match Y^{N1}/GDP and

Table 14: Stochastic Productivity Parameters

Parameter	Value	Description / Target
ρ^U	0.7	Persistence parameter of the idiosyncratic productivity shock for low-human-capital households.
ρ^X	0.75	Persistence parameter of the idiosyncratic productivity shock for medium-human-capital households.
ρ^S	0.685	Persistence parameter of the idiosyncratic productivity shock for high-human-capital households.
ρ^{SP}	0.685	Persistence parameter of the idiosyncratic productivity shock for high-human-capital households.
ρ^{SQ}	0.685	Persistence parameter of the idiosyncratic productivity shock for high-human-capital households.
$\sigma_{\varepsilon,U}^2$	0.0081	Variance of the idiosyncratic labor productivity shock for low-human-capital households.
$\sigma_{\varepsilon,X}^2$	0.0169	Variance of the idiosyncratic labor productivity shock for medium-human-capital households.
$\sigma_{\varepsilon,S}^2$	0.0225	Variance of the idiosyncratic labor productivity shock for high-human-capital households.
$\sigma_{\varepsilon,SP}^2$	0.0225	Variance of the idiosyncratic labor productivity shock for high-human-capital households.
$\sigma_{\varepsilon,SQ}^2$	0.0289	Variance of the idiosyncratic labor productivity shock for high-human-capital households.

Table 15: Market Income by Decile
Relative to Median Income

	Data	Model
Decile 1	0.2	0.1
Decile 2	0.4	0.3
Decile 3	0.6	0.5
Decile 4	0.8	0.7
Decile 5	1.0	1.0
Decile 6	1.2	1.4
Decile 7	1.5	1.8
Decile 8	1.8	2.2
Decile 9	2.3	2.8
Decile 10	> 2.3	> 2.8

Source: Statistics Canada, 2023, Census Profile, 2021 Census of Population; author calculations.

Y^{N2}/GDP , while G^{T1} is determined residually.

Transfers. Transfers consist of three components:

$$Trans = Trans^a + Trans^b + Trans^c.$$

The first component, $Trans^a$, captures income-tested transfers (e.g., child benefits), targeted to lower-income households and calibrated to approximately 1.8% of GDP. The second component, $Trans^b$, includes other transfers such as social assistance and tax credits, calibrated to 7.5% of GDP and primarily accruing to households below the median income. The third component, $Trans^c$, is endogenous and ensures that the government budget constraint holds; it is rebated lump-sum to all households.

Personal Income Taxes. We construct an economy-wide personal income tax schedule by combining federal and provincial statutory tax rates for 2025, aggregated using population weights. This yields a representative schedule capturing both levels and progressivity.

We approximate this schedule using the functional form in Lizarazo, Peralta-Alva, and Puy (2017):

$$\mathbb{T}(y^{ij}) = a_0 \left[y^{ij} - \frac{a_3}{a_0} \left((y^{ij})^{-a_1} + a_2 \right)^{-\frac{1}{a_1}} \right],$$

Table 16: Government's Parameters

Parameter	Value	Description / Target
<i>Expenditures</i>		
γ^G	0.21	Public consumption share of GDP; $\gamma^G = \frac{G}{GDP}$
$Trans^a$	0.018	Transfers related to child benefits as share of GDP targeted to households in the bottom 30% of the income distribution.
$Trans^b$	0.075	'Other' transfers as share of GDP.
<i>Personal Income Tax Function</i>		
a_0	0.5115	Asymptotic marginal tax rate (top tax rate) parameter as income tends to ∞ .
a_1	2.1308	Progressivity/curvature parameter controlling how fast marginal tax rises with income.
a_2	0.1985	Level/tax-free shifter parameter affecting how much income is effectively exempt from taxes.
a_3	0.2892	Scaling parameter shifting average rates without changing progressivity much.
<i>Consumption Taxes</i>		
τ^{T1}	0.1232	Consumption tax on $T1$. No tariffs are considered.
τ^F	0.1232	Consumption tax on F . No tariffs are considered.
τ^{N1}	0.1232	Consumption tax on $N1$.
τ^{N2}	0.1232	Consumption tax on $N2$.
<i>Intermediate Goods Taxes</i>		
$\tau^{T1,T1}$	0	No tax on intermediates from sector $T1$ into $T1$.
$\tau^{T1,N2}$	0	No tax on intermediates from sector $T1$ into $N2$.
$\tau^{N2,T1}$	0	No tax on intermediates from sector $N2$ into $T1$.
$\tau^{N2,N2}$	0	No tax on intermediates from sector $N2$ into $N2$.
<i>Tax on Factors</i>		
τ^W	0.076	Tax on wages, e.g., payroll tax on employees.
τ^D	0	No tax on distributed dividends.
τ^π	0.2304	Average corporate income tax rate.
τ^I	0.1265	Tax on investment.
<i>Subsidies</i>		
τ^Q	0.3054	Subsidy to R&D.

where y^{ij} denotes pre-tax income. Parameters (a_0, a_1, a_2, a_3) are estimated to match the observed average tax schedule. The resulting fit captures both marginal and average tax rates across the income distribution (Figure 17).

Consumption Taxes. Consumption taxes are constructed by combining the federal GST, provincial sales taxes (PST), and harmonized sales taxes (HST), accounting for cross-province heterogeneity. Rates are aggregated using population weights, yielding an average consumption tax rate of 12.32%.

Basic groceries are exempt from taxation, consistent with Canadian tax law. While tax rates vary across provinces, the model uses the population-weighted average as a representative rate (Table 17).

Table 17: Statutory Consumption Tax Rates
by Province and Territory (2025) (%)

	GST	HST	PST	Total Rate
Canada (population-weighted)	2.73	6.01	3.59	12.32
Alberta	5	–	–	5
British Columbia	5	–	7	12
Manitoba	5	–	7	12
New Brunswick	–	15	–	15
Newfoundland and Labrador	–	15	–	15
Northwest Territories	5	–	–	5
Nova Scotia	–	14	–	14
Nunavut	5	–	–	5
Ontario	–	13	–	13
Prince Edward Island	–	15	–	15
Quebec	5	–	9.98	15
Saskatchewan	5	–	6	11
Yukon	5	–	–	5

Notes: Basic groceries are zero-rated under the GST and HST and are exempt from provincial sales taxes in all jurisdictions. The Canada-wide rate is computed as a population-weighted average across provinces and territories.

Sources: Canada Revenue Agency; Queen’s University Financial Services; authors’ calculations.

Payroll Taxes. Payroll taxes correspond to employee contributions to public pension and insurance systems (CPP/QPP and EI). Using statutory rates and population weights (accounting for Québec), we obtain an average payroll tax rate of 7.6%.

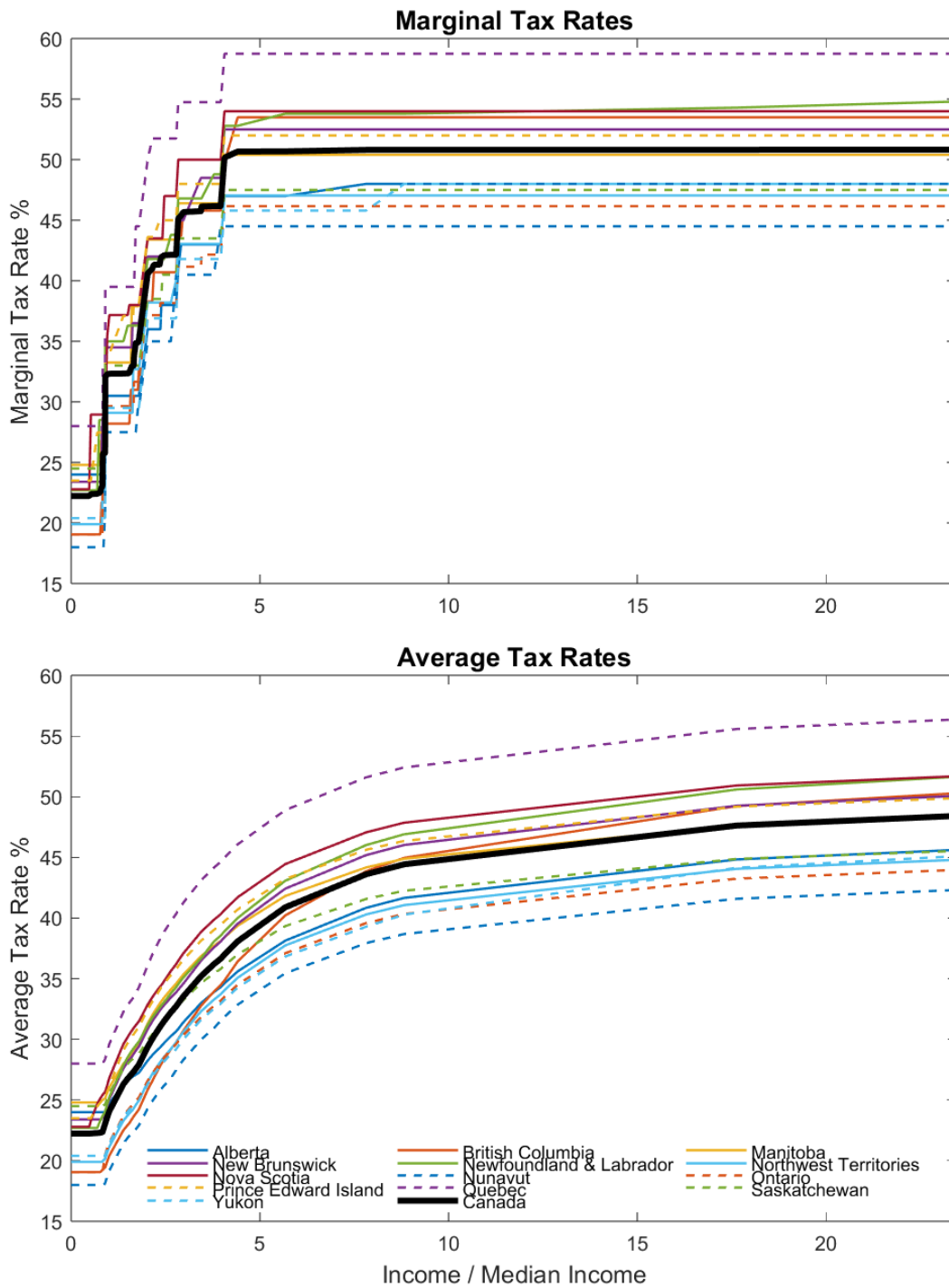


Figure 17: Marginal and Average Personal Income Tax Rates in Canada, 2025.
 Source: Canada Revenue Agency, 2025 (CRA); author's calculations.

Corporate Income Taxes. We construct an effective corporate income tax rate combining federal and provincial statutory rates, accounting for preferential regimes such as the small business deduction (SBD) and reduced manufacturing rates (Table 18).

Table 18: Corporate Income Tax Rates
by Province and Territory

Province/Territory	Corporate Tax Rate (%)
Alberta	10.00
British Columbia	12.00
Manitoba	12.00
New Brunswick	14.00
Newfoundland and Labrador	15.00
Northwest Territories	11.50
Nova Scotia	14.00
Nunavut	12.00
Ontario	11.50
Prince Edward Island	15.00
Quebec	11.50
Saskatchewan	12.00
Yukon	12.00
Population-weighted provincial rate	9.53
Effective federal corporate tax rate	13.51
Total corporate income tax rate	23.04

Notes: The effective federal corporate tax rate accounts for preferential regimes such as the small business deduction and manufacturing rate, assuming 21% of firms qualify for the SBD and 10% are manufacturing firms. Provincial rates are aggregated using population weights.

Source: Canada Revenue Agency; authors' calculations.

The federal component is constructed as:

- 21% of firms taxed at the SBD rate,
- 10% of firms taxed at the manufacturing rate,
- the remainder taxed at the general rate.

Using firm-share weights and population-weighted provincial rates, we obtain an aggregate corporate tax rate of 23.04% .

Dividend Taxes. Dividend distributions are not taxed at the corporate level beyond corporate income taxation. Accordingly, we set $\tau^D = 0$.

Investment Taxes. Investment taxation is calibrated using OECD, 2023 estimates of marginal effective tax rates (METR). The baseline value is set to 13.75%, with alternative values explored in sensitivity analysis.

Intermediate Goods Taxes. Under the GST/HST system, firms can reclaim taxes paid on intermediate inputs through input tax credits. We therefore set all intermediate input taxes to zero:

$$\tau^{T1,T1} = \tau^{T1,N2} = \tau^{N2,T1} = \tau^{N2,N2} = 0.$$

R&D Subsidies. R&D subsidies are calibrated using Innotax OECD, 2023 estimates for Canada. We focus on profitable firms, for which the implied subsidy rates are 31% for SMEs and 13% for large firms. Aggregating using firm shares (97.9% SMEs), we obtain $\tau^Q = 0.3062$.

This approach likely overstates the aggregate subsidy rate, as it weights by firm counts rather than R&D expenditure. However, this provides a conservative benchmark for evaluating the quantitative effects of R&D policies.

B.6 Additional Tables and Robustness

Additional calibration targets, intermediate steps, and robustness checks are available upon request.

C. Additional Figures

This appendix presents additional figures that complement the analysis in the main text. These figures provide background evidence and supporting information but are not central to the main quantitative results.

C.1 Education and Innovation

Figures 18 and 20 document cross-country relationships between education attainment and innovation outcomes. Figures 19 and 21 document cross-country relationships between education attainment and G7-countries outcomes.

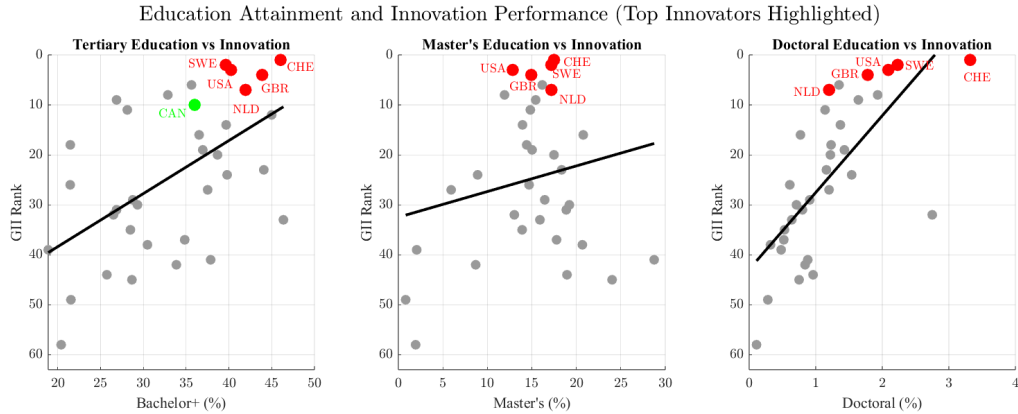


Figure 18: Education Attainment and Innovation Performance (Top Innovators Highlighted). Source: OECD, 2024b Indicators and Global Innovation Index (2023). Data on educational attainment (Bachelor's, Master's, Doctoral degrees) is compared with GII rank.

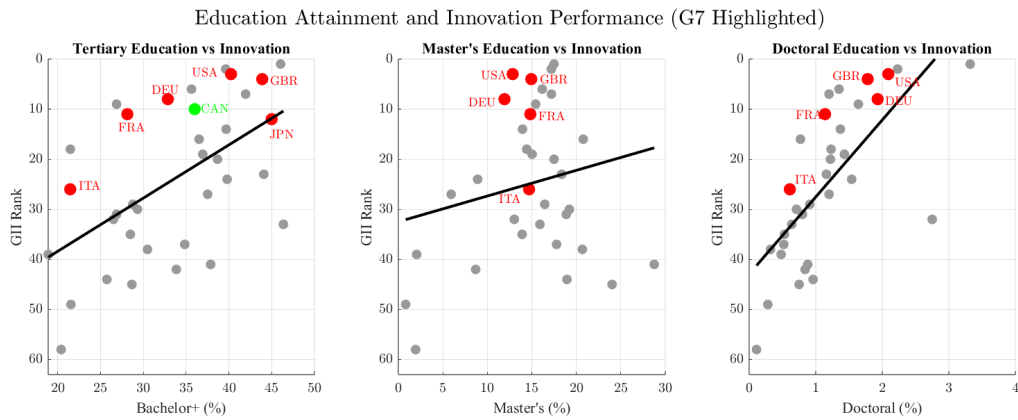


Figure 19: Education Attainment and Innovation Performance (G7 Countries Highlighted). Source: OECD, 2024b Indicators and Global Innovation Index (2023).

C.2 International Tax Comparisons

Figure 22 compares personal income tax schedules across G7 countries.

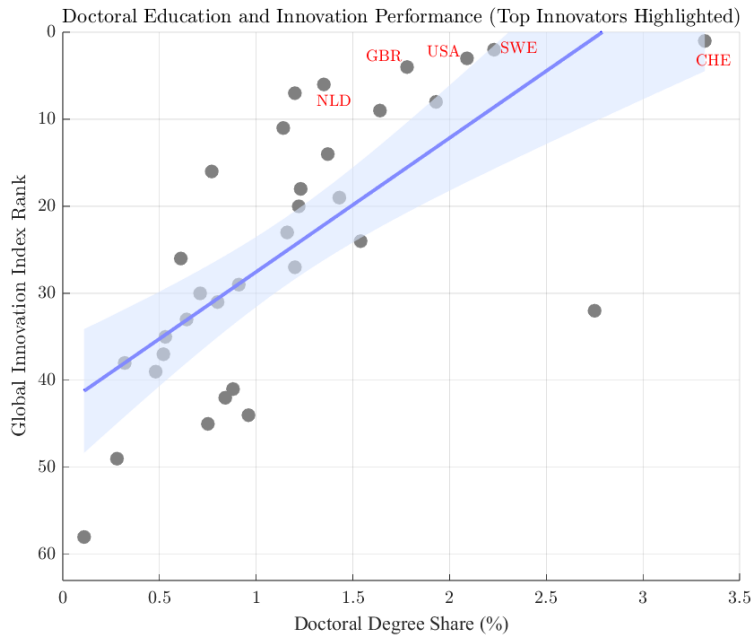


Figure 20: Doctoral Education vs Innovation Performance with Top Innovators labeled. Same source and interpretation as Figure 3.

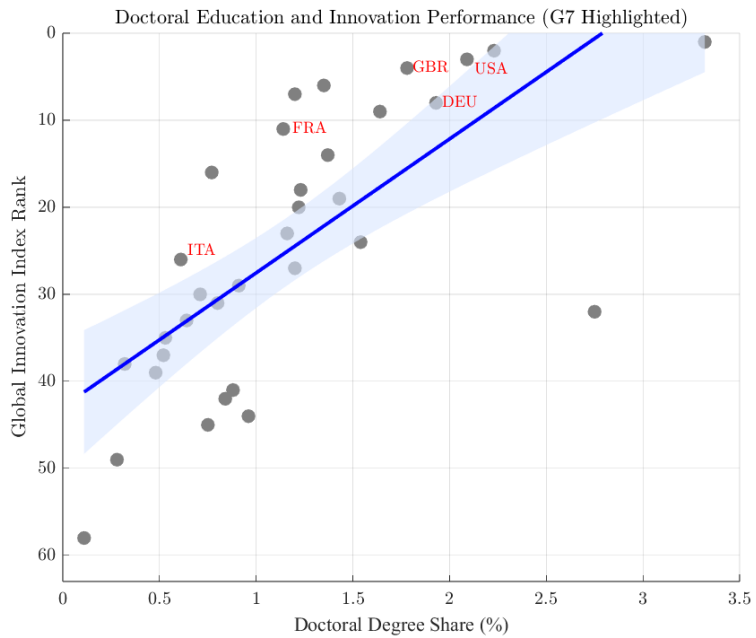


Figure 21: Doctoral Education vs Innovation Performance with G7 countries labeled. Confidence bands represent 95% prediction intervals for the regression of GII rank on doctoral degree share. Lower GII ranks indicate higher innovation performance.

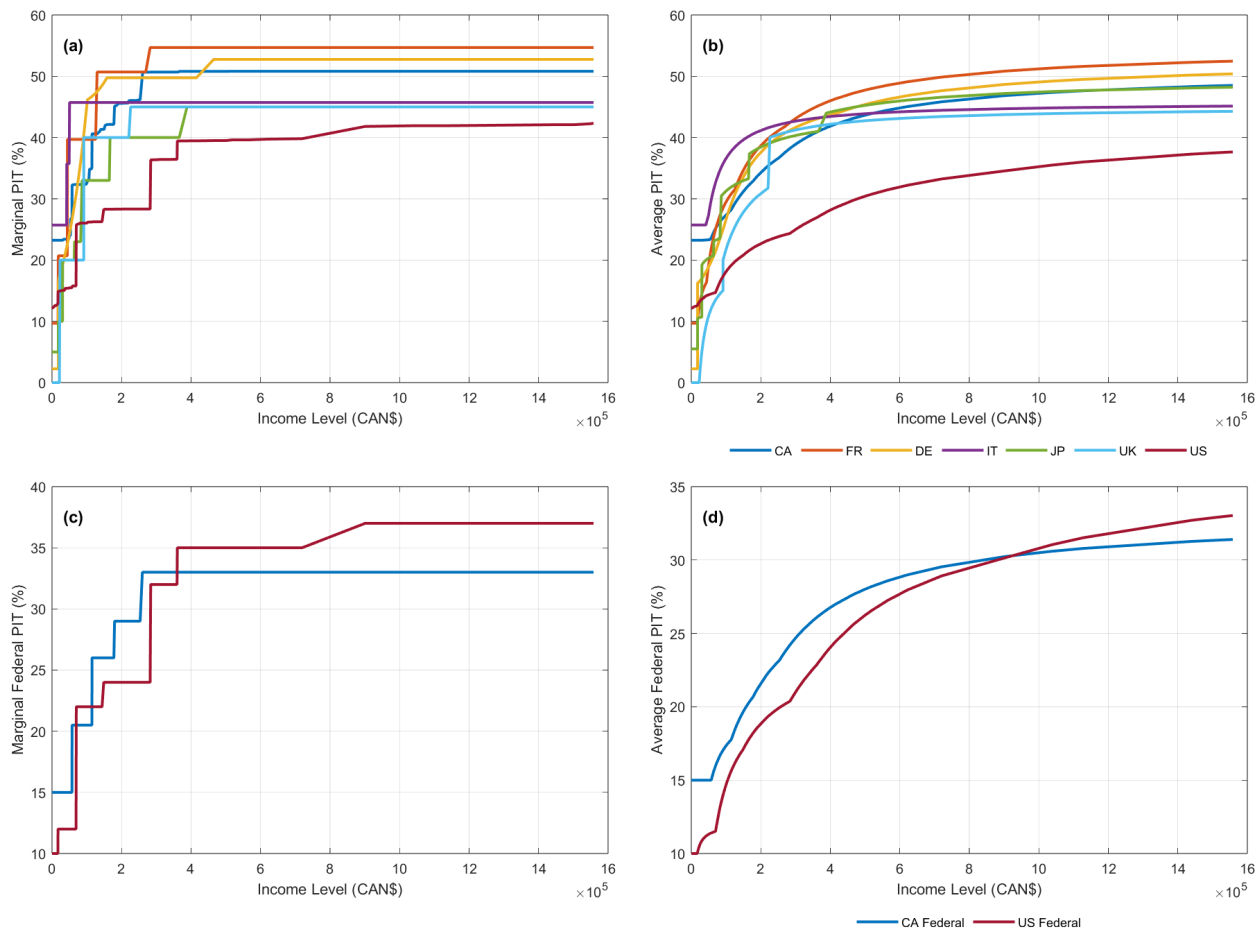


Figure 22: Personal income tax (PIT) rates across G7 countries in 2025. The figure reports marginal and estimated average PIT rates across income levels (in Canadian dollars, using the exchange rate as of December 31, 2024). Panels (A) and (B) present total PIT rates, while Panels (C) and (D) focus on federal schedules for Canada and the United States.

Source: Author's calculations based on official country tax schedules.

Notes: For Canada, total PIT rates combine federal and subnational taxes using population-weighted averages. For France, rates include the 9.7% *prélèvements sociaux*. For Germany, rates include the solidarity surcharge (*Solidaritätszuschlag*), modeled as a 5.5% progressive surcharge. For Italy, regional and municipal taxes are included using midpoints of their statutory ranges. For Japan, rates include prefectural (4%) and municipal (6%) taxes.



PUBLICATIONS

Innovation, Human Capital, and Taxation: Evidence from a Structural Model of the Canadian Economy

Working Paper No. WP/2026/116