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The R&D Tax Credit: Firm Dynamics, Employment, and Optimal Design*

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Abstract

R&D tax credits are a major instrument of innovation policy, yet little is known about their effects on job creation and firm dynamics, or how firms' ability to relabel non-R&D expenditures should shape their design. We develop a search-and-matching model with R&D investment and misreporting. Analytically, we show that the tax credit stimulates both R&D and job creation, that the expected gain from misreporting acts as a vacancy-posting subsidy, and that implementing the first best generally requires a proportional credit combined with a lump-sum component. We then estimate a life-cycle model with heterogeneous firms, endogenous entry and exit, and R&D spillovers using French data. R&D responds most strongly among small firms and, to a lesser extent, among young firms, while its response varies across technology levels. Employment responds most strongly among large and higher-technology firms. In the long run, each additional euro of tax credit raises declared R&D by approximately 1.5 euros but genuine R&D by only 0.7 euro, implying that more than half of the increase reflects relabeling. Re-optimizing statutory rates alone yields limited welfare gains. Introducing a minimum R&D requirement or targeting tax credits by firm age or size yields substantially larger gains. The optimal schedules favor younger firms and firms above an employment threshold. The size-dependent schedule yields the largest welfare gain, while increasing employment, output, genuine R&D, and the fiscal surplus.

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1 Introduction

With the rapid diffusion of information and communication technologies since the turn of the century, followed more recently by advances in artificial intelligence, stimulating firms' R&D investment has become a major concern for policymakers.[1] Governments devote substantial resources to subsidizing private R&D, yet the optimal design of these subsidies remains an open question. A large body of macroeconomic research, including Aghion and Howitt (2006), Aghion and Howitt (2008) and Acemoglu et al. (2018), emphasizes the role of innovation in driving productivity growth through improvements in product quality, technological progress, and heterogeneous firm capabilities. While this literature has extensively studied policies aimed at stimulating private R&D, innovation and patenting, much less attention has been paid to their effects on firm dynamics and employment. In particular, little is known about how innovation policies affect job creation and labor reallocation across firms of different sizes, ages, and productivity levels. In this paper, we study the French R&D tax credit through the lens of a search-and-matching model in which firms differ in size, age, productivity, and technology. We quantify the effects of the tax credit on labor-market outcomes, examine how technology persistence, knowledge spillovers, and firms' ability to relabel non-R&D expenditures as R&D influence these effects, and characterize the optimal design of the tax credit.

Several countries have introduced large-scale public programs to support R&D through grants, subsidies, public research funding, and tax incentives. France is one of the countries that support private R&D most actively, through the Crédit d'Impôt Recherche (CIR hereafter), the French R&D tax credit, introduced in 1983 to encourage firms' R&D investment by lowering its effective cost. Over time, this program has become the central pillar of French innovation policy and represents the country's largest instrument for supporting innovation, with about 7.5 billion euros in tax expenditures and around 30,000 declaring firms in 2022. A major reform in 2008 shifted the CIR from an incremental system, in which support depended on increases in R&D relative to previous years, to a volume-based system that grants firms a 30% tax credit on eligible R&D expenditures up to 100 million euros and 5% beyond that threshold.

[1] For instance, the European Commission's 2024-2029 agenda places competitiveness and innovation among its main priorities. Mario Draghi's recent report on the future of European competitiveness (Draghi, 2024) highlights Europe's innovation gap and outlines a broad set of policy recommendations.

The effectiveness and allocation efficiency of the CIR remain widely debated. Critics argue that, while the program lowers the private cost of research, it has not significantly closed France's innovation gap relative to leading economies such as the United States or China. Another concern is that the scheme disproportionately benefits large firms, which are better equipped to document and optimize eligible expenditures, while offering less support to younger or more financially constrained firms. Its broad-based design has been criticized for distributing public resources too diffusely rather than concentrating support on sectors with potentially larger social spillovers or on firms with greater innovation potential. These concerns echo those raised by Aghion et al. (2025). In the French policy debate, Jaravel (2022) and Aghion (2026) have also called for a reform of the CIR to reduce support to firms with very large R&D expenditures and to better target smaller firms. Their proposals reflect evidence that the effects of R&D tax credits on R&D investment are stronger among smaller firms.

In addition, because eligibility depends on firms' self-reported R&D expenditures, the system may create opportunities for misreporting, strategic relabeling, or the inclusion of expenditures only loosely connected to genuine innovative activity. Existing evaluations suggest that a non-negligible share (around 20%) of audited claims are partially or fully rejected due to accounting errors, overreporting, or misuse, raising broader concerns about public resource misallocation (Bach et al., 2021). If firms can obtain tax credits for expenditures that do not correspond to genuine R&D, evaluations based on declared R&D expenditures may overstate the effectiveness of the policy in stimulating innovation. Courtioux and Métivier (2022) also emphasize the difficulties of identifying eligible R&D expenditures and assessing firms' claims. The question is therefore not only whether innovation support is sufficiently generous, but whether it is effectively designed, targeted, and monitored to ensure that public investment genuinely fosters productivity growth and employment.

Although these contributions have identified important limitations of the CIR and suggested directions for reform, little is known about its optimal design in a quantitative framework that jointly accounts for firm heterogeneity, labor-market frictions, and misreporting. Our analysis addresses this question by characterizing welfare-maximizing tax-credit schedules and quantifying their effects on genuine R&D invest-

ment, employment, firm dynamics, and welfare.

We first develop a stylized search-and-matching model with R&D investment, which highlights the interplay between matching frictions and R&D expenditures. We show that the tax credit raises both R&D investment and job creation, with a larger employment semi-elasticity among high-technology firms than among low-technology firms. Greater persistence of technology increases R&D investment among low-technology firms and raises employment, while its effect on R&D investment among high-technology firms is ambiguous.

We then extend the toy model to R&D spillovers and fraud. For a given level of the tax credit, spillovers reduce R&D investment and introduce an additional channel through which the tax credit stimulates job creation. The ability of firms to misreport non-R&D expenditures as eligible R&D increases the expected gain from a vacancy, so that firms post more vacancies and employment increases: the gain from fraud acts as a subsidy for vacancy posting. Finally, we characterize the first-best allocation and show that implementing it generally requires combining a proportional tax credit with a lump-sum component. The proportional rate corrects the R&D investment distortion and is higher in the presence of spillovers, whereas the lump-sum component corrects vacancy posting. Fraud leaves the optimal proportional rate unchanged but lowers the lump-sum component required to reach the first best, since the expected gain from fraud already acts as a subsidy to job creation.

In the second part of the paper, we extend the framework to account for firm heterogeneity in age, size, and productivity, endogenous entry and exit, and general equilibrium effects through the labor market and R&D spillovers. The quantitative model is estimated on French data using the simulated method of moments and replicates, among other moments, the observed distributions of firms and tax credits by firm size and age. The analysis of the tax-credit multiplier shows that R&D spending responds more strongly among small firms and slightly more strongly among young firms. The long-run analysis also reveals heterogeneous R&D responses across technology levels. Employment responses follow a different pattern: they are substantially larger among large firms and among middle- and high-technology firms than among small and low-technology firms, while differences by firm age are limited. The model also implies substantial relabeling: in the long run, a one-euro increase in the tax credit raises de-

cleared R&D by approximately 1.5 euros, but genuine R&D by only 0.7 euro, so that slightly more than half of the increase in reported R&D reflects relabeled non-R&D expenditures.

Turning to policy design, re-optimizing the two statutory rates alone yields only limited welfare gains. Gains arise instead from reshaping the tax-credit schedule and from targeting it. The best-performing non-contingent schedule combines a minimum R&D expenditure requirement with a higher marginal credit rate below a lower R&D expenditure threshold. The optimal age-dependent schedule favors younger firms through a lower minimum R&D expenditure requirement, whereas the optimal size-dependent schedule assigns higher marginal rates to firms above an employment threshold of approximately 17 employees. Jointly optimizing the fraud penalty leaves the main features and ranking of these policies largely unchanged. The size-dependent schedule yields the largest welfare gain, reaching 5.3%, while increasing employment, output, genuine R&D expenditures, and the fiscal surplus, with virtually unchanged aggregate tax-credit expenditures. The main qualitative results are robust to alternative assumptions about spillovers and the strength of the entry channel.

Related literature

A large empirical literature has estimated the additional R&D expenditure generated per euro of forgone tax revenue, commonly referred to as the R&D tax multiplier (Duguet, 2012; Lokshin and Mohnen, 2012; Mulkay and Mairesse, 2013; Bozio et al., 2014; Rao, 2016; Lopez and Mairesse, 2018; Sterlacchini and Venturini, 2019; Agrawal et al., 2020; Bach et al., 2021; Appelt et al., 2023; Dechezleprêtre et al., 2023). Across countries and identification strategies, the multiplier is generally close to one on average, but substantially larger for small and young firms, which are more financially constrained. Recent theoretical work further argues that young firms contribute disproportionately to exploratory innovation, implying that firm heterogeneity plays a central role in aggregate innovation and productivity.

While the effects of innovation on employment have been widely studied, evidence on the labor-market effects of R&D tax incentives remains limited. Innovation generally has positive but heterogeneous effects on employment, with stronger effects for product innovations and high-technology firms (Vivarelli, 2014; Harrison et al., 2014; Calvino and Virgillito, 2018; Ugur et al., 2018; Hou et al., 2019). In contrast, only a few

papers directly evaluate the employment consequences of fiscal incentives, with existing evidence pointing to positive short-run employment effects (Bunel and Hadjibeyli, 2022). Empirical evidence also points to the inherently dynamic nature of innovation: R&D investment responds in the short run, but its effects on innovation and productivity typically materialize only after several years (Bloom et al., 2002; Bach et al., 2021). Understanding the impact of fiscal incentives therefore requires a dynamic framework capable of capturing these delayed effects.

Our framework accounts for several stylized facts documented in this literature. In particular, it reproduces the heterogeneous R&D multipliers observed across firms, captures the delayed effects of fiscal incentives on innovation and productivity, and links innovation to labor-market dynamics through endogenous job creation, job destruction, and worker reallocation in a frictional labor market.

The theoretical literature on R&D tax incentives builds primarily on models of endogenous growth (Aghion and Howitt, 1992; Ericson and Pakes, 1995; Klette and Kortum, 2004; Lentz and Mortensen, 2008). These models are based on stochastic firm innovations modeled as a Poisson process, and feature creative destruction, firm heterogeneity (in size, production lines, and/or productivity), imperfect competition, and sometimes firm entry and exit. Mortensen (2005) examines the effects of employer social security contributions and employment protection on innovation in an endogenous growth model with matching frictions *à la* Mortensen and Pissarides (1994). Our model also belongs to the search-and-matching literature and extends standard frameworks by incorporating heterogeneity in firm age, size, and productivity, which is key to understanding the effects of R&D tax credits.

Acemoglu et al. (2018) develop a model of innovation with creative destruction in which firms decide the number of production lines to open. Firms are heterogeneous in their innovative capacity and invest in R&D using skilled labor. Their innovations generate spillover effects, thereby causing market failures characterized by underinvestment in R&D. Akcigit et al. (2021) distinguish between basic research, which seeks to advance knowledge without aiming for a direct application, and applied research, which develops knowledge to meet a specific need; the public sector also contributes to the production of basic research. Akcigit et al. (2022) develop a model with technology spillovers in the absence of intellectual property rights, in which a firm's inno-

vation reduces production costs for other firms. Aghion et al. (2025) extend this type of framework by incorporating two sources of heterogeneity in firm markups: vertical innovation and process efficiency. The latter represents a firm's ability to circumvent regulations, expedite market authorization for new products, or erect barriers to entry for potential competitors; these activities do not generate technological spillovers. These papers study the misallocation of R&D and how tax-credit schemes can implement the socially optimal allocation. Aghion et al. (2023) examine how French labor regulations that become more stringent when firms reach 50 employees affect firms' incentives to innovate, and show that firms approaching the threshold reduce their innovation activity.

Overall, these theoretical studies highlight the central role of firm heterogeneity and innovation spillovers. However, frameworks building on Klette and Kortum (2004) typically link firm size to the number of product lines. In the absence of labor-market frictions or wage rigidities, employment therefore adjusts instantaneously when firms add or drop product lines, which contrasts with empirical evidence of delayed employment responses to innovation. Because our focus is on the effects of R&D tax credits on employment, firm dynamics, and the firm-size distribution, we build a framework in which firm size is measured by employment and adjusts subject to matching frictions. The model combines the firm-size distribution and matching frictions of Elsby and Michaels (2013), the firm dynamics of Hopenhayn (1992), innovation spillovers and technological obsolescence as in Klette and Kortum (2004), and the firm life-cycle dynamics of Sedláček (2020). This framework allows us to study how R&D tax credits affect employment growth, labor reallocation, and the distribution of firms by size and age.

Finally, we allow firms to report non-R&D expenditures as eligible R&D in order to receive a larger tax credit. This phenomenon, known as relabeling or strategic R&D classification, has been examined in a small number of studies (Hall and Van Reenen, 2000; Métivier et al., 2015; Chen et al., 2021; Bach et al., 2021; GOV.UK, 2024; Dai and Zou, 2025), which find that between 15% and 25% of declared R&D expenditures in R&D tax credit programs are relabeled. The paper most closely related to ours along this dimension is Chen et al. (2021), who examine the Chinese corporate income tax exemption program, which imposes a minimum level of R&D expenditure for eligibility.

Using variations in this threshold, they show that while the program encourages firms to engage in R&D, firms also relabel 24.2% of their expenditures as R&D. They also develop a static model in which firms with heterogeneous productivity choose their R&D intensity and can relabel expenditures as R&D at a cost in the event of an audit. We extend this analysis to a dynamic setting that accounts for the firm life cycle, firm size, spillovers, and general equilibrium effects.

The remainder of the paper is organized as follows. Section 2 develops the toy model and characterizes the optimal tax credit. Section 3 extends the model by introducing firm heterogeneity and entry and exit decisions. Section 4 describes the solution and estimation of the model. Section 5 explores the quantitative effects of tax-credit policies and their optimal design. Section 6 presents robustness checks. Section 7 concludes.

2 Toy model

To isolate the mechanisms linking R&D tax credits, innovation, and job creation, we develop a discrete-time search-and-matching model with R&D investment. The toy model illustrates how distortions arising from firms' R&D investment decisions interact with those associated with job creation in a frictional labor market.[2] Firms post vacancies to hire workers and invest in R&D to improve or maintain their technology. We initially assume that wages are exogenous.[3] We first characterize a benchmark economy and then introduce technology persistence, R&D spillovers, and tax-credit fraud. Finally, we characterize the Pareto allocation and the tax-credit schedule that implements it.

2.1 Environment

Assumption 1 (Available technologies) *$x \in \mathcal{X} = \{1, 2\}$ is the technology level, with $x = 1$ representing low and $x = 2$ representing high technology. We denote by y_x the productivity level associated with technology x, satisfying $y_2 > y_1 > 0$.*

[2] While externalities coming from competition are worth considering to address questions on innovation, the literature already extensively covers these issues. In addition, to keep the model tractable and analytically feasible we do not consider worker reallocation and creative destruction. These issues are introduced in the richer quantitative model.

[3] Appendix A.5 relaxes this assumption and introduces Nash bargaining.

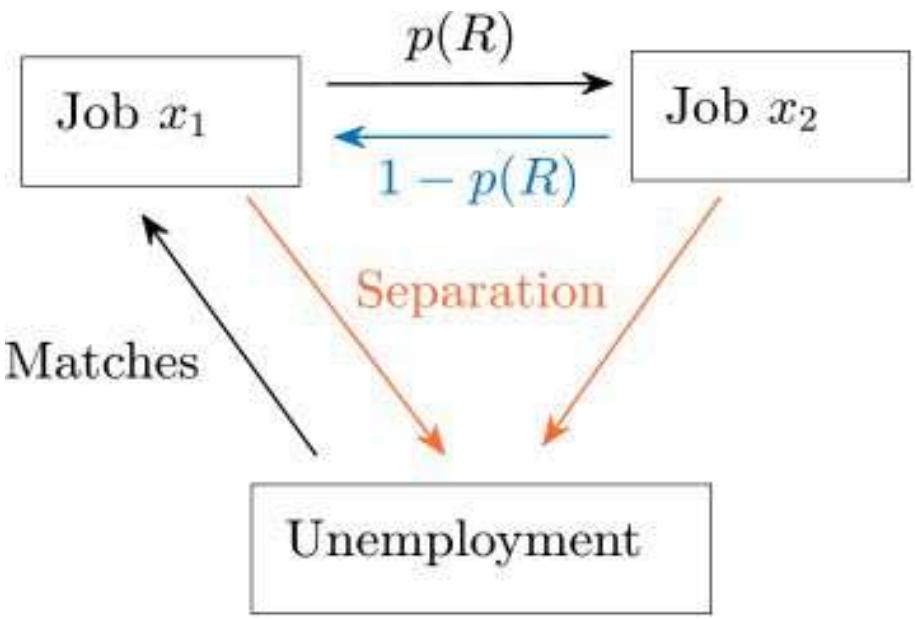
Assumption 2 (R&D investment and technology upgrading/downgrading) *The firm chooses the level of R&D expenditures, which affects the probability of switching technology levels. Let $p(R)$ denote the transition probability, which depends on the R&D investment R. We assume:*

$$p(R) = 1 - e^{-\phi R}, \tag{1}$$

where $\phi > 0$ represents the efficiency of R&D investment. The transition probability is increasing and concave in R&D investment.

For a low-technology firm, $p(R)$ is the probability of upgrading from $x = 1$ to $x = 2$. For a high-technology firm, $p(R)$ is the probability of remaining in $x = 2$; with probability $1 - p(R)$, the firm downgrades to $x = 1$.[4] Figure 1 summarizes the labor-market and technology transitions.

Figure 1: LABOR-MARKET AND TECHNOLOGY TRANSITIONS



Assumption 3 (R&D tax credit) *Firms receive an R&D tax credit: $C(R) = \kappa R$, with $\kappa \in [0, 1)$.*

In practice, the tax credit is offset against firms' tax liabilities and may be used over subsequent years. To abstract from the associated timing issues, we assume that the

[4]Note that under Assumption 2, for a given R&D investment, the probability of rising from the low state equals the probability of remaining in the high state. This assumption simplifies the model's solution and allows for analytical results.

credit is received immediately. This makes the policy equivalent to a direct R&D subsidy in the model, although we continue to refer to it as an R&D tax credit.

2.2 Benchmark economy with constant wage

2.2.1 Firms

Let q denote the job-filling rate, which is determined by the matching technology introduced below. Let c_v denote the vacancy-posting cost, $\beta \in (0,1)$ the discount factor, and $\delta \in (0,1)$ the exogenous firm-destruction probability. Labor is the sole input, and each firm employs at most one worker. Entrants start with low technology, $x = 1$.

Wage and productivity Let w_x denote the wage paid by a type-x firm and define $\pi_x \equiv y_x - w_x$ as its flow profit.

Assumption 4 (Productivity and wages) *The wage rate is exogenous, and productivity y_x and wage rate w_x satisfy:*

$$\pi_2 > \pi_1 > 0$$

The value of an existing firm A firm chooses its optimal level of R&D investment R_x for $x \in \{1,2\}$. The values of existing firms in states $x \in \{1,2\}$ satisfy:

$$J_x = \max_{R_x} \left\{ \pi_x - R_x(1-\kappa) + \beta(1-\delta)\Big[(1-p(R_x))J_1 + p(R_x)J_2\Big] \right\} \tag{2}$$

Optimal R&D investment The first-order condition for R&D investment is:

$$-1 + \kappa + \beta(1-\delta)p'(R_x)(J_2 - J_1) = 0, \quad x \in \{1,2\} \tag{3}$$

Hence, the firm's R&D investment is independent of the technology level: $R = R_1 = R_2$. The optimal R&D expenditure is:

$$R = \frac{1}{\phi}\log\left(\frac{\beta(1-\delta)\phi\Delta\pi}{1-\kappa}\right) \tag{4}$$

Remark 1 *In the absence of the tax credit ($\kappa = 0$), positive R&D investment requires $\beta(1-\delta)\phi\Delta\pi > 1$. We assume throughout that this condition holds. It then also ensures $R > 0$ for any $\kappa \in [0,1)$.*

Job creation An entering firm begins with low technology $x = 1$. The free-entry condition implies the standard job-creation condition:

$$\frac{c_v}{q} = \beta J_1 \tag{5}$$

The left-hand side is the expected cost of filling a vacancy, while the right-hand side is the discounted value of a newly created low-technology match.
Using equations (2) and (5), the equilibrium job-filling rate is:

$$\frac{c_v}{q} = \frac{\beta}{1-\beta(1-\delta)}\left\{\pi_1 - R(1-\kappa) + \beta(1-\delta)\left(1-e^{-\phi R}\right)\Delta\pi\right\} \tag{6}$$

with R satisfying (4).

2.2.2 Equilibrium employment

The population is normalized to one. Let n_1 and n_2 denote steady-state employment in firms of type $x = 1$ and $x = 2$, respectively, and let u denote unemployment. Total employment is given by $n = n_1 + n_2$, and $n + u = 1$. At equilibrium, outflows are equal to inflows in each stock:[5]

$$\underbrace{qv}_{\text{matches}} + \underbrace{(1-\delta)(1-p(R))n_2}_{\text{technology downgrade}} = \underbrace{\delta n_1}_{\text{separations}} + \underbrace{(1-\delta)p(R)n_1}_{\text{technology upgrade}}$$

$$\underbrace{(1-\delta)p(R)n_1}_{\text{technology upgrade}} = \underbrace{\delta n_2}_{\text{separations}} + \underbrace{(1-\delta)(1-p(R))n_2}_{\text{technology downgrade}}$$

$$\underbrace{qv}_{\text{matches}} = \underbrace{\delta(n_1+n_2)}_{\text{separations}}$$

Search and matching

Assumption 5 (Matching technology) *Unemployed workers and vacancies are matched accord-*

[5]These equations can be adapted to define the laws of motion of employment and unemployment.

ing to the following constant-returns matching function:

$$m = \chi u^{\rho} v^{1-\rho} \tag{7}$$

where $\chi > 0$ *measures matching efficiency and* $\rho \in (0,1)$ *is the elasticity with respect to unemployment.*

The vacancy-filling rate, the job-finding rate and the labor market tightness are given by $q = \frac{m}{v}$, $f = \frac{m}{u}$ and $\theta = v/u = f/q$, respectively. The job-finding rate can be expressed as follows:

$$f = \chi^{\frac{1}{\rho}} q^{-\frac{1-\rho}{\rho}} \tag{8}$$

Steady-state labor market equilibrium

$$u = \frac{\delta}{\delta + f} \tag{9}$$

$$n = \frac{f}{\delta + f} \tag{10}$$

$$n_1 = (1 - (1-\delta)p(R))n \tag{11}$$

$$n_2 = (1-\delta)p(R)n \tag{12}$$

2.2.3 Comparative statics

Proposition 1 (Impact on R&D investment) *An increase in the tax-credit rate* κ *enhances the profitability of R&D investment and thereby stimulates it.*

Proof

$$\frac{\partial R}{\partial \kappa} = \frac{1}{\phi} \frac{1}{1-\kappa} > 0.$$

□

Proposition 2 (Impact on labor market equilibrium) *An increase in the tax-credit rate* κ *reduces the vacancy-filling rate, that is:*

$$\frac{\partial q}{\partial \kappa} = -\frac{q^2}{c_v} \frac{\beta}{1 - \beta(1-\delta)} R < 0.$$

Proof See Appendix A.1.1. □

Corollary 1 *An increase in the tax-credit rate κ, through the reduction of the vacancy-filling rate, increases the job-finding rate, reduces unemployment, and raises total employment.*

$$\frac{\partial f}{\partial \kappa} = -\frac{1-\rho}{\rho}\theta\frac{\partial q}{\partial \kappa} > 0.$$

$$\begin{aligned}
\frac{\partial u}{\partial \kappa} &= -\frac{\delta}{(\delta+f)^2}\frac{\partial f}{\partial \kappa} < 0 \\
\frac{\partial n}{\partial \kappa} &= \frac{\delta}{(\delta+f)^2}\frac{\partial f}{\partial \kappa} > 0 \\
\frac{\partial n_2}{\partial \kappa} &= (1-\delta)p(R)\frac{\partial n}{\partial \kappa} + (1-\delta)np'(R)\frac{\partial R}{\partial \kappa} > 0
\end{aligned}$$

The impact on employment in low-technology firms is ambiguous due to a composition effect. Specifically:

$$\frac{\partial n_1}{\partial \kappa} = \underbrace{(1-(1-\delta)p(R))\frac{\partial n}{\partial \kappa}}_{\substack{\text{Increase in} \\ \text{total employment}}} - \underbrace{(1-\delta)np'(R)\frac{\partial R}{\partial \kappa}}_{\substack{\text{More firms} \\ \text{upgrade their technology}}}$$

The first term captures the expansion in aggregate employment, whereas the second captures the reallocation of employment toward high-technology firms through faster technology upgrading. Since these two forces work in opposite directions, the effect on employment in low-technology firms is ambiguous.

Comparison of semi-elasticities

Proposition 3 (Semi-elasticity) *The semi-elasticities of employment with respect to the tax-credit rate are higher for high-technology firms than for low-technology firms.*

$$\frac{1}{n_2}\frac{\partial n_2}{\partial \kappa} - \frac{1}{n_1}\frac{\partial n_1}{\partial \kappa} = \frac{1-p(R)}{p(R)}\phi\frac{n}{n_1}\frac{\partial R}{\partial \kappa} > 0$$

Proof See Appendix A.1.2. □

2.3 Persistence of the technology level

We introduce technology persistence by allowing a high-technology firm to remain in the high state even when its R&D investment does not succeed. Conditional on an unsuccessful R&D investment, the firm remains in $x = 2$ with probability $1 - \mu$ and downgrades to $x = 1$ with probability μ. This breaks the symmetry of the benchmark model: maintaining a high technology level requires less R&D effort than reaching it from the low state.

Firm values Type-1 and type-2 firms solve, respectively:

$$J_1 = \max_{R_1} \left\{ \pi_1 - R_1(1-\kappa) + \beta(1-\delta)\Big[(1-p(R_1))J_1 + p(R_1)J_2\Big] \right\} \tag{13}$$

$$J_2 = \max_{R_2} \left\{ \pi_2 - R_2(1-\kappa) + \beta(1-\delta)\Big[(1-p(R_2))(\mu J_1 + (1-\mu)J_2) + p(R_2)J_2\Big] \right\} \tag{14}$$

Optimal R&D investment and job creation

$$\begin{aligned} R_1 &= \frac{1}{\phi}\log\left(\frac{\beta(1-\delta)\phi\left\{\Delta\pi - \frac{1-\kappa}{\phi}\log(\mu)\right\}}{1-\kappa}\right) \\ R_2 &= R_1 + \frac{1}{\phi}\log(\mu) \end{aligned} \tag{15}$$

$$\frac{c_v}{q} = \frac{\beta}{1-\beta(1-\delta)}\left\{\pi_1 - R_1(1-\kappa) + \beta(1-\delta)\left(1-e^{-\phi R_1}\right)\left(\Delta\pi - \frac{1-\kappa}{\phi}\log(\mu)\right)\right\} \tag{16}$$

with R_1 satisfying (15). To save space, the detailed calculation and the labor market equilibrium are provided in Appendix A.2.1.

Impact of persistence

Proposition 4 (Impact on R&D) *An increase in technology persistence (a decrease in μ) increases R&D investment among low-technology firms, while its effect on R&D investment among high-technology firms is ambiguous.*

Proof

$$\frac{\partial R_1}{\partial \mu} = -\frac{1}{\phi}\frac{1}{\Delta\pi - \frac{1-\kappa}{\phi}\log(\mu)}\frac{1-\kappa}{\phi}\frac{1}{\mu} < 0$$

□

A lower value of μ increases the persistence of the high-technology state, since firms remain in the high state with probability $1-\mu$ even when R&D fails. This increases the value of reaching the high-technology state and therefore raises R&D investment among low-technology firms. By contrast, the effect of greater persistence on R&D investment among high-technology firms, R_2, is ambiguous.

Proposition 5 (Impact on vacancy-filling rate) *An increase in technology persistence (a decrease in μ) lowers the vacancy-filling rate.*

$$\frac{\partial q}{\partial \mu} = \frac{q^2}{c_v}\frac{\beta}{1-\beta(1-\delta)}\beta(1-\delta)\left(1-e^{-\phi R_1}\right)\frac{1-\kappa}{\phi}\frac{1}{\mu} > 0.$$

Proof See Appendix A.2.2. □

Impact of the tax credit with persistence

Proposition 6 (Tax-credit effects on R&D) *A higher tax-credit rate increases R&D investment for both types of firms. The R&D response to the tax-credit rate is weaker when technology is more persistent, that is, when μ is lower.*

Proof

$$\frac{\partial R_1}{\partial \kappa} = \frac{\partial R_2}{\partial \kappa} = \frac{1}{\phi}\frac{\Delta\pi}{(1-\kappa)\left(\Delta\pi - \frac{1-\kappa}{\phi}\log(\mu)\right)} > 0.$$

□

Proposition 7 (Tax-credit effects on labor-market outcomes) *A higher tax-credit rate lowers the vacancy-filling rate and raises the job-finding rate:*

$$\begin{aligned}\frac{\partial q}{\partial \kappa} &= -\frac{q^2}{c_v}\frac{\beta}{1-\beta(1-\delta)}\left\{R_1 - \beta(1-\delta)(1-e^{-\phi R_1})(R_1-R_2)\right\} < 0,\\ \frac{\partial f}{\partial \kappa} &= -\frac{1-\rho}{\rho}\theta\frac{\partial q}{\partial \kappa} > 0.\end{aligned}$$

Proof See Appendix A.2.3. □

2.4 R&D spillovers

Modeling the spillover We introduce an R&D externality by allowing average R&D investment, $\overline{R}$, to increase firms' technology-transition probabilities.[6] The parameter $\psi \geq 0$ governs the strength of this spillover.

$$p(R;\overline{R}) = 1 - e^{-\phi R - \psi \overline{R}} \tag{17}$$

Equilibrium R&D investment and vacancy-filling rate [7]

$$R = \frac{1}{\phi + \psi} \log \left\{ \frac{\beta(1-\delta)\phi\Delta\pi}{1-\kappa} \right\} \tag{18}$$

Relative to the benchmark without spillovers, equilibrium private R&D investment is lower (see Equation (4)).

$$\frac{c_v}{q} = \frac{\beta}{1-\beta(1-\delta)} \left\{ \pi_1 - R(1-\kappa) + \beta(1-\delta) \left(1 - e^{-(\phi+\psi)R} \right) \Delta\pi \right\} \tag{19}$$

with R satisfying (18) and $R = \overline{R}$.

Impact of spillovers

Proposition 8 (Investment) *The parameter $\psi \geq 0$ governs the intensity of the spillover effect. When $\psi = 0$, no spillover arises, which corresponds to the benchmark case (Section 2.2). As the magnitude of the spillover increases, equilibrium private R&D investment decreases.*

Proof

$$\frac{\partial R}{\partial \psi} = -\frac{1}{(\phi+\psi)^2} \log \left\{ \frac{\beta(1-\delta)\phi\Delta\pi}{1-\kappa} \right\} = -\frac{R}{\phi+\psi} < 0$$

□

[6] We consider the effect of the average R&D investment in the economy. Alternatively, it would be possible to consider aggregate R&D investment or aggregate technology. In that case, as is well known in the endogenous growth literature, the equilibrium would depend on the size of the economy. For tractability reasons, we investigate this case only in the quantitative model.

[7] See Appendix A.3.1.

Proposition 9 (Vacancy-filling rate) *A stronger spillover induces firms to post more vacancies and therefore lowers the vacancy-filling rate.*

$$\frac{\partial q}{\partial \psi} = -\frac{q^2}{c_v}\frac{\beta}{1-\beta(1-\delta)}\frac{(1-\kappa)R}{\phi+\psi} < 0$$

Proof See Appendix A.3.2. □ A stronger spillover affects vacancy creation through two opposing channels. First, it reduces firms' own R&D investment, which lowers the value of a vacancy. Second, it directly raises the probability of technological improvement for a given level of private R&D, which increases the value of a vacancy. The second channel dominates, so firms post more vacancies and the vacancy-filling rate falls.

Impact of the tax credit with spillovers

Proposition 10 (Investment) *A higher tax-credit rate raises R&D investment, but the response is weaker in the presence of spillovers.*

Proof

$$\frac{\partial R}{\partial \kappa} = \frac{1}{\phi+\psi}\frac{1}{1-\kappa} > 0 \tag{20}$$

□

Proposition 11 (Vacancy-filling rate) *An increase in the tax-credit rate lowers the vacancy-filling rate. One has:*

$$\frac{\partial q}{\partial \kappa} = -\frac{q^2}{c_v}\frac{\beta}{1-\beta(1-\delta)}\left\{ \underbrace{R}_{\substack{R\&D \\ channel}} + \underbrace{\frac{\beta(1-\delta)\psi e^{-(\phi+\psi)R}\Delta\pi}{(\phi+\psi)(1-\kappa)}}_{\substack{Spillover \\ channel}} \right\} < 0$$

Proof See Appendix A.3.3. □

2.5 Tax-credit fraud

The firm may misreport non-R&D expenditures as eligible R&D in order to increase its tax-credit claim. Denote by $s \geq 0$ the amount of non-R&D expenditure misreported as eligible R&D. We impose $s \leq w_x$, so that misreported expenditures correspond to existing labor costs that are not genuine R&D. Total reported R&D expenditure is therefore $R + s$. Let p_a denote the probability that the firm is audited. Conditional on an audit, misreporting is detected with probability $h(s)$. If detected, the firm pays a fine of $(1 + \tau_f)\kappa s$, where τ_f is the penalty rate applied when fraud is proven.
We assume that the detection probability $h(s)$ is given by:

$$h(s) = \left(\frac{s}{\bar{s}}\right)^{\zeta} \quad s \in [0, \bar{s}]$$

with $\bar{s} > 0$ and $\zeta > 1$. This specification captures the idea that the probability of detecting and establishing deliberate misreporting during an audit increases with the amount of misreported expenditure.

2.5.1 Equilibrium with tax credit fraud

Firm value A firm of type-x, with $x \in \{1, 2\}$, solves:[8]

$$\begin{aligned} J_x &= \max_{R_x, s_x} \Big\{ y_x - w_x - R_x + \kappa(R_x + s_x) + \beta(1-\delta)\Big[(1 - p(R_x))J_1 + p(R_x)J_2 \\ &- p_a h(s_x)(1+\tau_f)\kappa s_x\Big]\Big\}, \qquad (21) \\ x &= 1, 2. \end{aligned}$$

$$R = \frac{1}{\phi}\log\left\{\frac{\beta(1-\delta)\phi\Delta\pi}{1-\kappa}\right\} \qquad (22)$$

$$s = \bar{s}\left(\frac{1}{\beta(1-\delta)p_a(1+\tau_f)(1+\zeta)}\right)^{\frac{1}{\zeta}} \qquad (23)$$

Note that optimal R&D investment and the amount of misreported expenditure are independent. This separability follows from the assumptions adopted to preserve an-

[8] See Appendix A.4.1 for the derivation of the optimal values of R and s.

alytical tractability.

Job creation

$$\frac{1-\beta(1-\delta)}{\beta}\frac{c_v}{q} = \pi_1 - R + \kappa(R+s) + \beta(1-\delta)\left\{(1-e^{-\phi R})\Delta\pi - p_a(1+\tau_f)\kappa s\left(\frac{s}{\bar{s}}\right)^{\zeta}\right\} \quad (24)$$

Equilibrium employment is described by the equations of Section 2.2.2.

2.5.2 Comparison with the benchmark economy (Section 2.2)

Proposition 12 (Fraud and job creation) *Fraud increases the expected gain from a vacancy. Firms therefore post more vacancies, and the vacancy-filling rate is lower. In other words, the gain from fraud acts as a subsidy for vacancy posting.*

$$q^\star > q^f, \quad f^\star < f^f, \quad \theta^\star < \theta^f, \quad u^\star > u^f, \quad n^\star < n^f$$

where $X^\star$ and X^f denote the equilibrium values in the benchmark economy and the economy with tax-credit fraud, respectively.

Proof See Appendix A.4.2. □

Comparative statics

Proposition 13 (R&D investment and misreporting) *An increase in the tax-credit rate increases R&D investment and has no effect on the amount of non-R&D expenditure reported as R&D.*

Proof Differentiating gives:

$$\frac{\partial R}{\partial \kappa} = \frac{1}{\phi}\frac{1}{1-\kappa} > 0$$
$$\frac{\partial s}{\partial \kappa} = 0$$

□

Proposition 14 (Vacancy-filling rate) *An increase in the tax credit reduces the vacancy-filling rate. One has:*

$$\frac{\partial q}{\partial \kappa} = -\frac{\beta}{1-\beta(1-\delta)}\frac{q^2}{c_v}\left(R + \frac{s\zeta}{1+\zeta}\right) < 0$$

Proof See Appendix A.4.3. □

Corollary 2 (Semi-elasticities) *For sufficiently small values of $\kappa \geq 0$, the semi-elasticities of the vacancy-filling rate with respect to the tax-credit rate κ satisfy:*

$$\frac{1}{q^f}\frac{\partial q^f}{\partial \kappa} \quad < \quad \frac{1}{q^\star}\frac{\partial q^\star}{\partial \kappa} \quad < 0$$

Proof See Appendix A.4.4. □

2.6 Pareto allocation

2.6.1 Pareto allocation in the benchmark economy

The social planner's allocation solves the following recursive program:[9]

$$W(n_1, n_2) = \max_{\{v,u,R_1,R_2,n_1',n_2'\}} \left\{ n_1 y_1 + n_2 y_2 + bu - c_v v - R_1 n_1 - R_2 n_2 + \beta W(n_1', n_2') \right\}$$

$$\begin{cases} n_1' = \chi u^\rho v^{1-\rho} + (1-\delta)n_1 - (1-\delta)p(R_1)n_1 + (1-\delta)(1-p(R_2))n_2 & (\Gamma_1) \\ n_2' = (1-\delta)n_2 + (1-\delta)p(R_1)n_1 - (1-\delta)(1-p(R_2))n_2 & (\Gamma_2) \\ 1 - n_1 - n_2 - u = 0 & (\Phi) \end{cases}$$

We allow for home production $b \geq 0$. The optimal R&D investment and vacancy-filling rate are given by the following expressions:

$$R = \frac{1}{\phi}\log\left(\beta(1-\delta)\phi\Delta y\right) \tag{25}$$

$$\frac{c_v}{q} = \frac{\beta}{1-\beta(1-\delta)}\left\{(1-\rho)(y_1 - b - R) - \rho\theta c_v + \beta(1-\delta)(1-e^{-\phi R})(1-\rho)\Delta y\right\} \tag{26}$$

Implementing the Pareto allocation in the benchmark economy

Proposition 15 *Consider the allocation with a constant wage (Section 2.2). Suppose the tax credit is of the form $C(R) = \kappa_0 + \kappa_1 R$.*[10] *The equations giving the equilibrium values of R and*

[9] The detailed calculations are presented in Appendix A.6.1.

[10] Note that the tax credit has a lump-sum component. The equations in Section 2.2 should therefore be adapted accordingly.

q are:

$$R = \frac{1}{\phi}\log\left(\frac{\beta(1-\delta)\phi(\Delta y - \Delta w)}{1-\kappa_1}\right)$$

and

$$\frac{c_v}{q} = \frac{\beta}{1-\beta(1-\delta)}\left\{y_1 - w_1 - R(1-\kappa_1) + \kappa_0 + \beta(1-\delta)\left(1-e^{-\phi R}\right)(\Delta y - \Delta w)\right\}.$$

Identifying these expressions with equations (25)–(26), we deduce the values of κ_0 and κ_1 that implement the Pareto allocation:

$$\begin{aligned}
\kappa_1 &= \frac{\Delta w}{\Delta y} \\
\kappa_0 &= (1-\rho)(y_1 - b - R) - (y_1 - w_1) + R(1-\kappa_1) - \rho\theta c_v \\
&+ \beta(1-\delta)(1-e^{-\phi R})(\kappa_1 - \rho)\Delta y
\end{aligned}$$

where θ is the Pareto allocation value of labor market tightness.

Remark 2 *A strictly proportional R&D tax credit does not generally implement the Pareto allocation. The proportional component κ_1 can restore the Pareto-optimal level of R&D investment, but it does not generally correct the distortion in vacancy creation. Because wage setting also affects firms' incentives to post vacancies, a second instrument is required. The lump-sum component κ_0 provides this additional margin and allows the Pareto-optimal vacancy-filling rate to be implemented. This result highlights a distortion in firms' R&D investment decisions arising from surplus sharing between firms and workers. When workers capture part of the productivity gains associated with technological upgrading, firms do not internalize the full social return to their R&D investment. In the absence of a wage differential across technology levels ($\Delta w = 0$), this distortion disappears and the optimal proportional tax-credit rate is zero. This intra-firm distortion interacts with the standard congestion externality arising from vacancy creation in a frictional labor market, as firms do not internalize the effect of their vacancy-posting decisions on the vacancy-filling rate.*

2.6.2 Pareto allocation with R&D spillovers

The social planner's allocation solves the following recursive program:

$$W(n_1,n_2)=\max_{\{v,u,R_1,R_2,n_1',n_2'\}}\left\{n_1y_1+n_2y_2+bu-c_vv-R_1n_1-R_2n_2+\beta W(n_1',n_2')\right\}$$

$$\begin{cases} n_1'=\chi u^{\rho}v^{1-\rho}+(1-\delta)n_1-(1-\delta)p(R_1;R_1)n_1+(1-\delta)(1-p(R_2;R_2))n_2 & (\Gamma_1)\\ n_2'=(1-\delta)n_2+(1-\delta)p(R_1;R_1)n_1-(1-\delta)(1-p(R_2;R_2))n_2 & (\Gamma_2)\\ 1-n_1-n_2-u=0 & (\Phi)\end{cases}$$

The social planner internalizes the spillover externality, so that the R&D optimality conditions depend on the following derivative: $p_R(R_x;R_x)+p_{\overline{R}}(R_x;R_x)$. We therefore substitute $p_R(R_x;R_x)+p_{\overline{R}}(R_x;R_x)$ for $p_R(R_x)$ in equations (80)-(81) of Appendix A.6.1.

$$R = \frac{1}{\phi+\psi}\log\left(\beta(1-\delta)(\phi+\psi)\Delta y\right) \quad (27)$$

$$\frac{c_v}{q} = \frac{\beta}{1-\beta(1-\delta)}\left\{(1-\rho)(y_1-b-R)-\rho\theta c_v+\beta(1-\delta)(1-e^{-(\phi+\psi)R})(1-\rho)\Delta y\right\} \quad (28)$$

Implementing the Pareto allocation in the economy with spillovers

Proposition 16 *Consider the allocation with a constant wage and R&D spillovers (Section 2.4). Suppose the tax credit is of the form* $C(R)=\kappa_0+\kappa_1R$.[11] *The equations giving the equilibrium values of* R *and* q *are:*

$$R = \frac{1}{\phi+\psi}\log\left\{\frac{\beta(1-\delta)\phi(\Delta y-\Delta w)}{1-\kappa_1}\right\}$$

and

$$\frac{c_v}{q} = \frac{\beta}{1-\beta(1-\delta)}\left\{y_1-w_1+\kappa_0-R(1-\kappa_1)+\beta(1-\delta)\left(1-e^{-(\phi+\psi)R}\right)(\Delta y-\Delta w)\right\}.$$

[11] Note that the tax credit has a lump-sum component, that is κ_0. The equations in Section 2.4 should therefore be adapted accordingly.

Identifying these expressions with equations (27)–(28), we deduce:

$$\begin{aligned}\kappa_1 &= 1-\frac{\phi}{\phi+\psi}\left(1-\frac{\Delta w}{\Delta y}\right)\\ \kappa_0 &= (1-\rho)(y_1-b-R)-(y_1-w_1)+R(1-\kappa_1)-\rho\theta c_v\\ &+ \beta(1-\delta)(1-e^{-(\phi+\psi)R})\left(1-\rho-(1-\kappa_1)\frac{\phi+\psi}{\phi}\right)\Delta y\end{aligned}$$

where θ is the Pareto allocation value of labor market tightness.

Remark 3 *As in the case of Proposition 15 and Remark 2, implementing the Pareto allocation is not possible with a simple proportional tax credit. The R&D investment optimality condition is affected by both the fixed-wage assumption (Assumption 4) and the R&D spillover externality. The proportional component κ_1 corrects the distortions affecting R&D investment, while the lump-sum component κ_0 corrects the distortion in vacancy creation.*

Remark 4 *Comparing the tax-credit rates in Propositions 15 and 16, let $\kappa_1^\star$ and κ_1^S denote the rates that implement the Pareto allocation in the benchmark economy and in the economy with spillovers, respectively. Then,*

$$\kappa_1^S-\kappa_1^\star = 1-\frac{\phi}{\phi+\psi}\left(1-\frac{\Delta w}{\Delta y}\right)-\frac{\Delta w}{\Delta y} = \left(1-\frac{\Delta w}{\Delta y}\right)\left(1-\frac{\phi}{\phi+\psi}\right) > 0$$

Hence, the proportional tax-credit rate required to implement the Pareto allocation is higher in the presence of R&D spillovers. The reason is that firms do not internalize the positive effect of their R&D investment on other firms' technology transitions, which leads to underinvestment in R&D in the decentralized equilibrium. A higher tax-credit rate is therefore required to correct this additional distortion.

2.6.3 Implementation of the Pareto allocation with fraud monitoring

Proposition 17 *Consider the allocation with a constant wage and tax credit fraud. Suppose the tax credit is of the form $C(R+s) = \kappa_0+\kappa_1(R+s)$. The equations determining the equilibrium values of R, s, and q are:*

$$\begin{aligned}R &= \frac{1}{\phi}\log\left\{\frac{\beta(1-\delta)\phi(\Delta y-\Delta w)}{1-\kappa_1}\right\},\\ s &= \left[\frac{1}{\beta(1-\delta)p_a(1+\tau_f)(1+\zeta)}\right]^{\frac{1}{\zeta}}\bar{s},\end{aligned}$$

and

$$\begin{aligned}\frac{1-\beta(1-\delta)}{\beta}\frac{c_v}{q} &= y_1 - w_1 + \kappa_0 - R(1-\kappa_1) + \beta(1-\delta)\left(1-e^{-\phi R}\right)(\Delta y - \Delta w)\\ &+ \kappa_1 s - \beta(1-\delta)p_a\left(\frac{s}{\bar{s}}\right)^{\zeta}\kappa_1 s(1+\tau_f).\end{aligned}$$

Note that the gain from fraud, using the optimality condition for s, reduces to:

$$\kappa_1 s - \beta(1-\delta)p_a\left(\frac{s}{\bar{s}}\right)^{\zeta}\kappa_1 s(1+\tau_f) = \frac{\zeta}{1+\zeta}s\kappa_1.$$

For given values of the audit probability p_a and the penalty rate τ_f, matching these expressions to equations (25)–(26) yields the values of κ_1 and κ_0 that implement the Pareto allocation:

$$\begin{aligned}\kappa_1 &= \frac{\Delta w}{\Delta y},\\ \kappa_0 &= (1-\rho)(y_1 - b - R) - (y_1 - w_1) + R(1-\kappa_1) - \rho\theta c_v\\ &+ \beta(1-\delta)(1-e^{-\phi R})(\kappa_1 - \rho)\Delta y - \frac{\zeta}{1+\zeta}s\kappa_1.\end{aligned}$$

where θ is the Pareto allocation value of labor market tightness.

Remark 5 *The proportional component of the tax credit is the same as in Proposition 15. Fraud does not affect the value of $\kappa_1 = \frac{\Delta w}{\Delta y}$ required to implement the Pareto-optimal level of R&D investment.*

By contrast, the lump-sum component is different. Comparing the value in the benchmark economy (i.e., $\kappa_0^\star$; see Proposition 15) with the value obtained when tax credit fraud is possible (i.e., κ_0^f; see Proposition 17), we obtain:

$$\kappa_0^f - \kappa_0^\star = -\frac{\zeta}{1+\zeta}s\kappa_1 < 0.$$

The lump-sum component of the tax credit necessary to implement the Pareto allocation is therefore lower when fraud is possible. More precisely, κ_0 is reduced by the expected gain from fraud. Ultimately, the gain from fraud reduces the subsidy required to implement the Pareto allocation.

Remark 6 *Suppose $\kappa_0 = 0$. The value of the penalty rate τ_f implementing the Pareto allocation,*

if it exists, would satisfy:

$$\frac{\zeta}{1+\zeta}\kappa_1\left[\frac{1}{\beta(1-\delta)p_a(1+\tau_f)(1+\zeta)}\right]^{\frac{1}{\zeta}}\bar{s}=(1-\rho)(y_1-b-R)-(y_1-w_1)$$
$$+R(1-\kappa_1)-\rho\theta c_v+\beta(1-\delta)(1-e^{-\phi R})\left(\kappa_1-\rho\right)\Delta y$$

2.7 Nash bargaining

The benchmark model assumes exogenous wages to preserve analytical tractability. To assess whether the policy-implementation results depend on this assumption, Appendix A.5 derives the equilibrium under Nash bargaining, while Appendix A.6 derives the Pareto allocation and compares it with the decentralized equilibrium. Under the Hosios condition, when firms do not internalize the effect of R&D on negotiated wages, the two-instrument logic remains: a proportional tax credit can restore the Pareto-optimal R&D level but does not in general implement the Pareto-optimal vacancy-creation condition. When firms fully internalize the wage response to R&D, the Hosios condition is sufficient for the decentralized benchmark allocation to be Pareto efficient in the absence of spillovers and without any tax credit. These results highlight the interaction between the distortion arising from surplus sharing within firms and the matching externalities associated with vacancy creation. Correcting the R&D investment distortion through a proportional tax credit may itself distort firms' vacancy-posting decisions, even when the Hosios condition holds.

3 Quantitative model

The toy model highlights the interaction between R&D investment and job creation but abstracts from several dimensions that are important for assessing the aggregate effects of R&D tax credits, including worker heterogeneity, labor reallocation, the firm-size and age distributions, and creative destruction through endogenous firm entry and exit. To account for these dimensions, we extend the framework to a dynamic life-cycle model in which idiosyncratic productivity and employment adjustment frictions generate an endogenous firm-size distribution, as in Elsby and Michaels (2013), while firms evolve over the life cycle as in Sedláček (2020). The model builds on Albertini

et al. (2024), in which firms are characterized by a technology level. We extend their framework by allowing technology to evolve endogenously through R&D investment. Firm entry and exit are endogenous, following Hopenhayn (1992), and we introduce directed search as in Menzio et al. (2016), with search segmented across technology-specific labor markets. The model also incorporates the key ingredients introduced in the previous section: technology persistence, R&D spillovers, and tax-credit fraud.

3.1 Heterogeneities

R&D process and technology level. Firms are characterized by a technology level $x \in \mathcal{X} = \{x_1, \ldots, x_X\}$, with technology levels ordered in ascending order. Changes in technology depend on both firm-level R&D investment and aggregate technology. Let R denote firm-level R&D investment and $\bar{x}$ aggregate technology, defined below. We use aggregate technology rather than average R&D in order to capture both the technology level of firms and the mass of firms operating in the economy.

Let $p(R, \bar{x})$ denote the probability of a technology-improvement event. For $i < X$, such an event moves the firm from technology level x_i to x_{i+1}, while a firm already at the highest technology level x_X remains at x_X. We assume that this probability is increasing and concave in both firm-level R&D investment and aggregate technology:

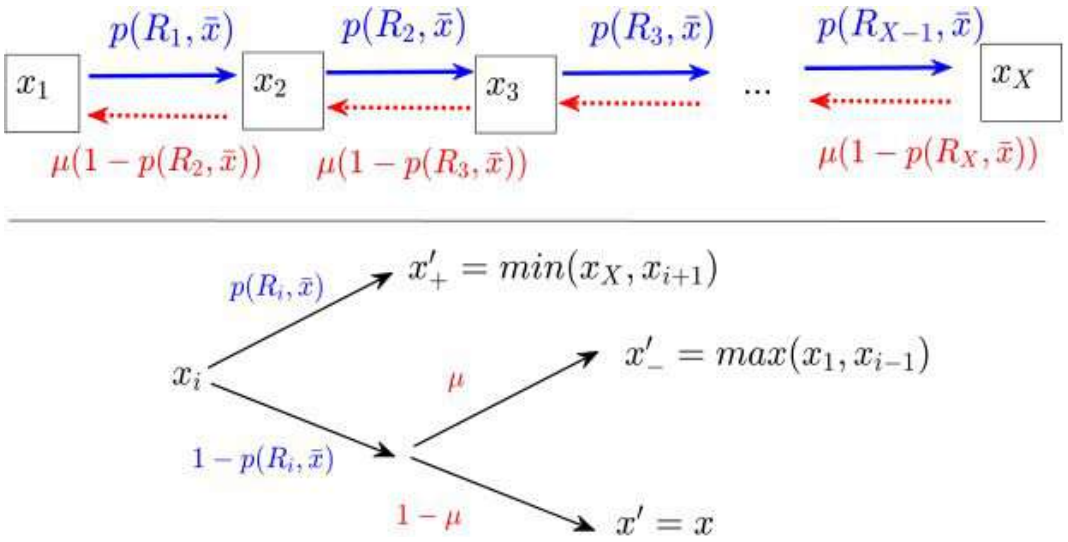
$$\frac{\partial p(R,\bar{x})}{\partial R} > 0, \qquad \frac{\partial p(R,\bar{x})}{\partial \bar{x}} > 0,$$

and

$$\frac{\partial^2 p(R,\bar{x})}{\partial R^2} < 0, \qquad \frac{\partial^2 p(R,\bar{x})}{\partial \bar{x}^2} < 0.$$

With probability $p(R, \bar{x})$, the firm's technology moves to $x'_+ = x_{\min\{i+1,X\}}$. Conditional on no technology improvement, technology depreciates to $x'_- = x_{\max\{i-1,1\}}$ with probability μ and remains unchanged with probability $1 - \mu$. Figure 2 illustrates the technology-transition process.

Figure 2: R&D PROCESS



Labor force by skill level. The labor force is heterogeneous across skill types. Let $L(x)$ denote the mass of workers with skill type associated with technology level x. The distribution of the labor force across skill types is endogenous, while the total labor force L is exogenous and satisfies $L = \sum_x L(x)$. Let $u(x)$ and $N(x)$ denote, respectively, the masses of unemployed and employed workers of type x. An employed worker's skill type evolves with the technology of the firm in which the worker is employed. An unemployed worker of type x_i, with $i > 1$, moves to skill type x_{i-1} with probability ν. Workers of type x_1 remain at the lowest skill level.

Firm size. Firm size is measured by employment, denoted by $n \in \mathcal{N} = [0, \infty)$.

Idiosyncratic productivity shocks. Firms are subject to idiosyncratic productivity shocks. Let $\varepsilon \in \mathcal{E} = (0, \infty)$ denote the idiosyncratic component of firm productivity. Each period, incumbent firms draw a new productivity level ε' from the conditional distribution $G(\varepsilon'|\varepsilon)$. Entering firms, in contrast, draw their initial productivity level from the unconditional distribution $G_0(\varepsilon')$.

Age. Firms are characterized by age a. Let $\mathcal{A} = \{a_1, \ldots, a_A\}$ denote the set of possible ages, with $a_i = i$ for $i = 1, \ldots, A$. Firms enter the market at age a_1. Age increases deterministically by one period, from a_i to a_{i+1}. Once a firm reaches the maximum age

a_A, it remains in this terminal age group until exit or exogenous destruction.

3.2 Directed search

The labor market is segmented by technology level x. A type-x worker searches only for jobs associated with technology level x. The labor market is frictional, so search and recruiting are costly and time-consuming. Matching in submarket x is represented by:

$$m(x) = m(u(x), \boldsymbol{v}(x)) \tag{29}$$

where $u(x)$ is the mass of type-x unemployed workers and $\boldsymbol{v}$ the mass of vacancies posted by firms in submarket x. The matching function is increasing, concave and exhibits constant returns to scale. The job-finding and vacancy-filling rates are, respectively,

$$f(x) = \frac{m(x)}{u(x)} = m(1, \theta(x)) \tag{30}$$

$$q(x) = \frac{m(x)}{\boldsymbol{v}(x)} = m(\theta(x)^{-1}, 1) \tag{31}$$

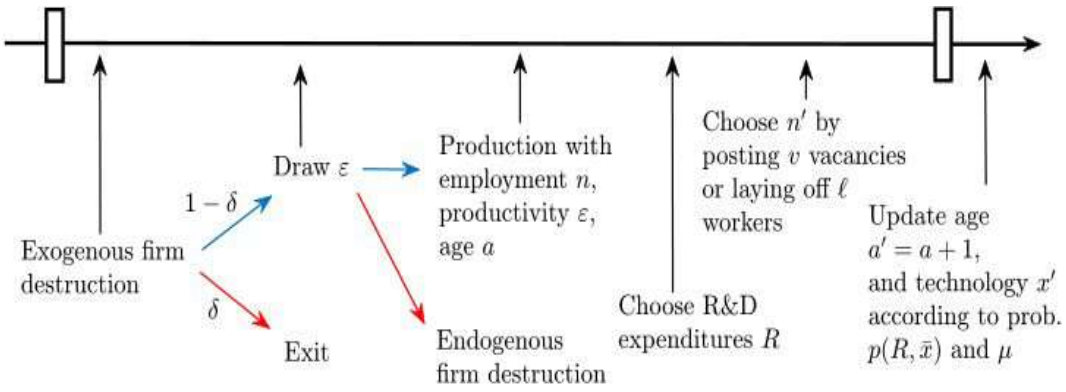
where $\theta(x)$ represents the labor market tightness, defined as follows:

$$\theta(x) = \frac{\boldsymbol{v}(x)}{u(x)} \tag{32}$$

3.3 Incumbent firms

An incumbent firm is characterized by a state denoted by the four-tuple $(n, x; \varepsilon, a)$. Current and next-period employment are denoted by n and n', respectively, with $n, n' \in \mathcal{N}$. At the beginning of the period, a firm may be destroyed exogenously with probability δ. A surviving firm draws a new productivity level ε' from the conditional distribution $G(\varepsilon'|\varepsilon)$. Figure 3 summarizes the within-period timing of shocks, production, R&D investment, and employment adjustment decisions.

Figure 3: TIMING OF EVENTS



Flow (gross) profit Firms produce a homogeneous consumption good traded in a competitive market. Production uses labor n and technology x. Output of a firm employing n workers, operating at technology level x, and with idiosyncratic productivity ε is given by the following CES production function:

$$y(n, x; \varepsilon) \quad = \quad \varepsilon(\alpha n^{\iota} + (1-\alpha)x^{\iota})^{1/\iota}$$

where $\alpha \in (0, 1)$ is the share of labor in the production function and ι governs the elasticity of substitution between the two production factors.
We consider the following wage-setting rule (Bagger et al., 2014; Blundell et al., 2016):

$$w(x; \varepsilon) \quad = \quad \xi(\varepsilon x)^{\gamma}$$

where $\gamma \in [0, 1]$ determines the wage curvature with respect to productivity εx. When $\gamma < 1$, productivity changes translate into less-than-proportional changes in wages.
The flow (gross) profit is given by:

$$\pi(n, x; \varepsilon) \quad = \quad y(n, x; \varepsilon) - nw(x; \varepsilon)$$

Employment adjustment The firm determines its optimal employment level through hiring and layoffs. To hire new workers, the firm posts vacancies. Let v denote the number of posted vacancies. A firm posting v vacancies incurs a convex cost given by $c_v \frac{v^2}{2}$, with $c_v > 0$. Given the vacancy-filling rate $q(x)$, the number of hires is $h = q(x)v$.

The firm may also fire workers. Let ℓ denote the number of layoffs. The firm incurs a linear cost given by $c_d\ell$ with $c_d > 0$. Hiring and layoff decisions are made in the current period and determine next-period employment. Finally, the firm may choose the *status quo*, without hiring or firing ($v = 0$ and $\ell = 0$). Employment therefore evolves according to:

$$n' \;=\; n + h - \ell = n + qv - \ell$$

Note that as workers employed by the firm are identical, the firm cannot fire and hire simultaneously. Consequently, if $v > 0$, then $\ell = 0$ and if $\ell > 0$, then $v = 0$. We can also have $v = 0$ and $\ell = 0$. The adjustment cost function takes the following form:

$$\varphi(n, n'; q(x)) \;=\; \frac{c_v}{2}\left(\underbrace{\frac{n'-n}{q(x)}\mathbb{1}_{n'>n}}_{v}\right)^2 + c_d\,\underbrace{(n-n')\mathbb{1}_{n'<n}}_{\ell}.$$

Program of incumbent firms We denote by $\Pi(n, x; \varepsilon, a)$ the value of a firm in state $(n, x; \varepsilon, a)$. Recall that the age of the firm evolves exogenously ($a' = \min\{a+1, a_A\}$) and that exogenous individual shocks are drawn from the conditional distribution $G(\varepsilon'|\varepsilon)$. The firm chooses next-period employment n' (through the control variables v and ℓ), R&D investment R, and the amount of non-R&D expenditure reported as R&D, s given the state $(n, x; \varepsilon, a)$ by solving the following program:

$$\begin{aligned}
\Pi(n,x;\varepsilon,a) \;=\; \max_{n',R,s}\Bigg\{ & \underbrace{\overbrace{(\pi(n,x;\varepsilon) - \varphi(n,n';q) - R)}^{\text{After tax profit}}(1-\tau(B))}_{B\text{: taxable profit}} + \underbrace{C(R+s)}_{\text{Tax credit}} - \overbrace{n\,c_o(x)}^{\substack{\text{Operating}\\ \text{costs}}} \qquad (33)\\
& + \underbrace{\beta(1-\delta)\Big[\sum_{x'} Z(x,x';R,\bar{x}) \int \Lambda(n',x';\varepsilon',a')dG(\varepsilon'|\varepsilon) - p_a h(s)(1+\tau_f)[C(R+s) - C(R)]\Big]}_{\text{Expected profits}} \Bigg\}\\
\text{with} \qquad & \Lambda(n',x';\varepsilon',a') \;=\; \mathbb{1}_{W>U}\,\max[\Pi(n',x';\varepsilon',a'), -c_{x'}] \;+\; \mathbb{1}_{W\leq U}(-c_{x'}) \qquad (34)
\end{aligned}$$

with the non-R&D expenditures

$$0 \;\leq\; s \;\leq\; \bar{s} = n\,w(x;\varepsilon) + \varphi(n,n';q) + n\,c_o(x) \qquad (35)$$

Firm profits (output minus labor costs and R&D expenditures) are subject to the corporate tax $\tau(B)$ which, in the case of France, depends on the amount of profit. The firm decides the R&D and non-R&D expenditures, thereby receiving a tax credit of $C(R+s)$. The firm faces operating costs that are increasing with technology ($c_o'(x) > 0$), proportional to firm size, and are non-tax-deductible.[12] We assume that the firm can only reclassify existing non-R&D expenses as eligible R&D. Let $\bar{s}$ be the maximum value for s. It corresponds to the wage bill, employment-adjustment costs, and operating costs. p_a denotes the audit probability, while $h(s)$ is the probability that misreporting is detected conditional on an audit. If misreporting is detected, the firm repays the tax credit unduly received and pays an additional penalty at rate τ_f on this amount. The expected profit corresponds to the discounted payoff given the evolution of the state variables minus the expected cost of the fraud. Because wages are not bargained, inefficient separations may arise. If $W < U$, workers quit and the firm closes.[13] In addition, if the continuation value falls below the exit value $-c_x$, the firm exits. The firm's decision rules are expressed as follows:

$$\begin{aligned} n' &= n + q(x)v - \ell = \mathcal{D}(n, x; \varepsilon, a) \\ R &= \mathcal{D}_R(n, x; \varepsilon, a) \\ s &= \mathcal{D}_s(n, x; \varepsilon, a) \end{aligned}$$

3.4 New firms

Program of a new firm An entering firm starts at the lowest technology level, x_1. The firm chooses next-period employment n' and R&D investment R by solving:

$$\Pi_0 = \max_{n', R} \left\{ -\varphi(n, n'; q) - R + \beta \sum_{x'} Z(x_1, x'; R, \bar{x}) \int \Pi(n', x', \varepsilon', a_1) dG_0(\varepsilon') \right\} \quad (36)$$

The entry process is the following. The firm enters the market and posts v vacancies. The firm also invests an amount R in R&D. Each vacancy is filled with probability $q(x_1)$, so that the firm hires $n' = q(x_1)v$ workers. The firm operates next period, at age $a = a_1$, with n' workers. With probability $p(R, \bar{x})$, technology is upgraded to the next level, x_2. We assume that new firms are

[12] Examples include fines and penalties, non-business expenses, excessive executive compensation, non-deductible vehicle depreciation, entertainment expenses, and certain donations.

[13] Recall that all workers within the firm are identical. If one worker in the firm is better off unemployed, then all workers in that firm will be also better off.

not eligible for the tax credit. The firm's decision rules are given by:

$$\begin{aligned} R &= \mathcal{D}_{0,R} \\ n' &= q(x_1)v = \mathcal{D}_0 \end{aligned}$$

Entry condition Let c_e be the entry cost. Without entry frictions, new firms enter the market until profit opportunities are exhausted, that is:

$$\Pi_0 \geq c_e \tag{37}$$

At equilibrium, the above condition binds and determines the mass of entrants e. Following Sedláček (2020), we allow for frictions in the firm-entry process. These frictions may reflect coordination problems that prevent all potential entrants from successfully entering the market, so that the mass of actual entrants may be lower than the number of entry attempts. Such entry frictions are also in the spirit of the literature on innovation and R&D investment (Saint-Paul, 2002; Klette and Kortum, 2004; Acemoglu et al., 2018). To capture these frictions, we assume that the mass of entering firms e satisfies:

$$e = \eta_0 + \eta_1(\Pi_0 - c_e) \tag{38}$$

This specification of entry frictions is used by Albertini et al. (2024) and is in line with Moll (2017). The elasticity of the supply of entrants is governed by the parameter η_1. As $\eta_1 \to \infty$, the supply of entrants becomes infinitely elastic and the frictionless free-entry condition, $\Pi_0 = c_e$, is recovered.

Exit Firms exit the market if $\Pi(n, x; \varepsilon, a) < -c_x$. Let $\mathcal{D}_e(n, x; \varepsilon, a)$ denote the exit decision rule, defined as an indicator taking value 1 if the firm exits and 0 otherwise. Thus,

$$\mathcal{D}_e(n, x; \varepsilon, a) = \mathbb{1}\left\{\Pi(n, x; \varepsilon, a) < -c_x\right\}. \tag{39}$$

3.5 Workers

An employed worker's skill type evolves with the technology of the firm employing her. Unemployed workers may also experience skill depreciation independently of any firm. In this section, we define the values of employed and unemployed workers. An employed worker is characterized by the state of her employer, $(n, x; \varepsilon, a)$. Let $W(n, x; \varepsilon, a)$ denote the value of an

employed worker. When the employment relationship ends, the worker retains the skill type x associated with her former employer. This skill type may subsequently evolve as described in Section 3.1. Let $U(x)$ denote the value of an unemployed worker of type x.

Employed workers Given the firm's employment and R&D decisions, $n' = \mathcal{D}(n, x; \varepsilon, a)$ and $R = \mathcal{D}_R(n, x; \varepsilon, a)$, respectively, the value of an employed worker satisfies the following recursive equation:

$$
\begin{aligned}
W(n,x;\varepsilon,a) \;=\; & w(x;\varepsilon) + \beta\Bigg\{ \overbrace{\left(\delta + (1-\delta)\mathbb{1}_{n'<n}\frac{n-n'}{n}\right)U(x)}^{\text{Firm exit or separation}} \\
& + \;(1-\delta)\Bigg(\underbrace{\mathbb{1}_{n'\geq n}}_{\substack{\text{Expanding}\\ \text{firm}}} + \underbrace{\mathbb{1}_{n'<n}\frac{n'}{n}}_{\substack{\text{Contracting}\\ \text{firm}}} \Bigg) \underbrace{\sum_{x'} Z(x,x';R,\bar{x}) \int_{\varepsilon'} \Omega(n',x';\varepsilon',a') dG(\varepsilon'|\varepsilon)}_{\text{Expected continuation value}} \Bigg\} \\
\text{with} \qquad & \Omega(n',x';\varepsilon',a') \;=\; \mathbb{1}_{\Pi>-c_x} \max(W(n',x';\varepsilon',a'), U(x')) + \mathbb{1}_{\Pi\leq -c_x} U(x')
\end{aligned}
\tag{40}
$$

The value of employment consists of the current wage w and the continuation value. With probability δ, the firm is exogenously destroyed and the worker becomes unemployed, receiving $U(x)$. Conditional on firm survival, if the firm contracts, the worker is laid off with probability $\mathbb{1}_{n'<n}\frac{n-n'}{n}$ and also receives $U(x)$. Otherwise, the worker remains employed with probability $\mathbb{1}_{n'\geq n} + \mathbb{1}_{n'<n}\frac{n'}{n}$. In this case, the continuation value depends on the subsequent evolution of the firm's technology and productivity. The value $\Omega(\cdot)$ further accounts for endogenous firm exit and for the worker's option to quit: if the firm exits, the worker becomes unemployed and receives $U(x')$; if the firm remains active, the worker chooses between remaining employed, with value $W(n', x'; \varepsilon', a')$, and becoming unemployed, with value $U(x')$.

Unemployed workers The value of an unemployed worker of type x satisfies the following recursive equation:

$$
\begin{aligned}
U(x) \;=\; & b(x) + \beta\Big\{ (1-f(x))\Big[\nu U(x'_-) + (1-\nu)U(x)\Big] + f(x)\mathcal{W}(x) \Big\} \\
\text{with} \qquad & x'_- = x_{\max\{i-1,1\}}
\end{aligned}
\tag{41}
$$

The unemployed worker receives unemployment benefits $b(x)$ that depend on x.[14] With probability $1 - f(x)$ she does not meet a firm. In that case she may experience a decline in her skill with probability ν. With probability $f(x)$ she gets a contact with a firm and has an expected payoff $\mathcal{W}(x)$. It should be noted that at the time of the contact the worker does not know the size, the productivity and the age of the firm, but she knows the distribution of the firms over the different states. More precisely, the expected value $\mathcal{W}(x)$ depends on the distribution of the vacant jobs. It is given by:

$$\begin{aligned}\mathcal{W}(x) &= \overbrace{\vartheta(x)\sum_a \int\int \sum_{x'} Z(x,x';R,\bar{x})\omega(n;\varepsilon,a|x)\Omega(n',x';\varepsilon',a')dG(\varepsilon'|\varepsilon)d\varepsilon dn}^{\text{Incumbent firms, } R=\mathcal{D}_R(n,x;\varepsilon,a),\ n'=\mathcal{D}(n,x;\varepsilon,a)} \\ &+ \underbrace{(1-\vartheta(x))\sum_{x'} Z(x,x';\mathcal{D}_{0,R},\bar{x})\int \Omega(n',x';\varepsilon',a_1)dG_0(\varepsilon')}_{\text{New firms, } R=\mathcal{D}_{0,R},\ n'=\mathcal{D}_0}. \end{aligned} \tag{42}$$

$\vartheta(x)$ is the share of incumbent firms among all firms. $\omega(n;\varepsilon,a|x)$ corresponds to the proportion of vacant jobs of type x in firms of size n, technology x, and age a. They are defined in the next section.

3.6 Stationary distribution of firms and workers

The stationary distribution of firms, denoted by $f_d(n,x;\varepsilon,a)$, satisfies:

$$\begin{aligned} f_d(n',x';\varepsilon',a') &= \overbrace{(1-\delta)\sum_x Z(x,x';\mathcal{D}_R(n,x;\varepsilon,a),\bar{x})\int\int \mathbb{1}_{n'=\mathcal{D}(n,x;\varepsilon,a)} f_d(n,x;\varepsilon,a)g(\varepsilon'|\varepsilon)d\varepsilon dn}^{\text{Incumbent firms}} \\ &+ \underbrace{e\sum_x Z(x,x';\mathcal{D}_{0,R},\bar{x})g_0(\varepsilon')\mathbb{1}_{n'=\mathcal{D}_0}\mathbb{1}_{a'=a_1}\mathbb{1}_{x=x_1}}_{\text{New firms}} \end{aligned} \tag{43}$$

Let $f_d^i(n,x;\varepsilon,a) = f_d(n,x;\varepsilon,a) - e\mathbb{1}_{n=D_0}\mathbb{1}_{x=x_1}\mathbb{1}_{a=a_1}g_0(\varepsilon)$ be the distribution of incumbent firms. The share of incumbent firms $\vartheta(x)$ is given by:

$$\vartheta(x) = \frac{\sum_a \int\int f_d^i(n,x;\varepsilon,a)dnd\varepsilon}{\sum_x\sum_a \int\int f_d(n,x;\varepsilon,a)dnd\varepsilon} \tag{44}$$

[14] The dependence of b on x is a reduced form of unemployment benefits being proportional to past wage. As the wage is an increasing function of x, we simply consider that b is also an increasing function of x. x declines over time if the worker remains unemployed. We believe this modelling captures the decline in unemployment benefits with unemployment duration. Keeping track of the wage history when the employed worker becomes unemployed would be highly difficult in this setup. To avoid cumbersome computation, we adopt this simplification.

The contact distribution from incumbent firm can be written as:

$$\begin{aligned} \omega(n;\varepsilon,a|x) &= \frac{f_d^i(n,x;\varepsilon,a)v(n,x;\varepsilon,a)}{\sum_a \int_n \int_\varepsilon f_d^i(n,x;\varepsilon,a)v(n,x;\varepsilon,a)d\varepsilon dn} \\ \text{with} \qquad v(n,x;\varepsilon,a) &= \frac{n'-n}{q(x)}\mathbb{1}_{n'>n}, \quad n' = \mathcal{D}(n,x;\varepsilon,a) \end{aligned} \tag{45}$$

The stationary distributions of employment and unemployment are given by:

$$n_d(n,x;\varepsilon,a) = n \times f_d(n,x;\varepsilon,a), \tag{46}$$

$$u(x) = \underbrace{u(x)(1-f(x))(1-\nu\mathbb{1}_{x>x_1})}_{\substack{\text{Stay unemployed} \\ \text{No skill depreciation}}} + \underbrace{S(x)}_{\text{Separation}} + \underbrace{\mathbb{1}_{x<x_X}u(x')(1-f(x'))\nu}_{\text{Skill depreciation}}, \tag{47}$$

with $S(x)$ being the number of separations from all firms with technology x:

$$S(x) = \sum_a \int\int \sum_{x'} Z(x',x;R,\bar{x})[(n-n')\mathbb{1}_{n'<n}(1-\delta)+\delta n]f_d(n,x';\varepsilon,a)dn\, d\varepsilon.$$

3.7 Market clearing

Let $L(x)$ denote the labor force of skill type x, and let L denote the total labor force. They satisfy:

$$L = \sum_x L(x), \tag{48}$$

$$\text{with } L(x) = N(x) + u(x), \tag{49}$$

$$\text{and } N(x) = \sum_a \int\int n_d(n,x;\varepsilon,a)\, d\varepsilon\, dn. \tag{50}$$

The aggregate number of vacancies in submarket x, which enters the matching function, is given by:

$$\boldsymbol{v}(x) = \sum_a \int\int f_d(n,x;\varepsilon,a)v(n,x;\varepsilon,a)\, d\varepsilon\, dn. \tag{51}$$

Aggregate technology, which generates R&D spillovers through the technology-upgrading probability, is given by:

$$\bar{x} = \sum_x \sum_a \int\int f_d(n,x;\varepsilon,a)\, x d\varepsilon\, dn. \tag{52}$$

In the absence of a specific financing scheme for unemployment benefits, the fiscal surplus is rebated to households through a lump-sum transfer T. One has:

$$\begin{aligned} FS &= \sum_x \sum_a \int_n \int_\varepsilon f_d(n,x;\varepsilon,a)\Big[\tau(B) + p_a h(s)(1+\tau_f)[C(R+s) - C(R)] - C(R+s)\Big] d\varepsilon dn \\ &\quad - \sum_x b(x)u(x), \qquad (53) \\ T &= FS. \qquad (54) \end{aligned}$$

Note that B, R and s depend on the state $(n, x; \varepsilon, a)$.

3.8 Equilibrium

Definition 1 (Equilibrium) *Given exogenous processes for age a and idiosyncratic productivity ε, an x-dependent unemployment insurance policy $b(x)$ and a tax-and-subsidy policy $(\tau(B), C(R+s))$, the equilibrium is a list of (i) quantities and probabilities $m(x)$, $\boldsymbol{v}(x)$, $\theta(x)$, $f(x)$, $q(x)$; (ii) value functions $\Pi(n,x;\varepsilon,a)$ and Π_0; (iii) optimal decisions $\mathcal{D}(n,x;\varepsilon,a)$, $\mathcal{D}_R(n,x;\varepsilon,a)$, $\mathcal{D}_0$, and $\mathcal{D}_{0,R}$; (iv) entry mass e, share of incumbent firms $\vartheta(x)$ and conditional distribution of vacancies $\omega(n;\varepsilon,a|x)$; (v) stationary distribution of employed and unemployed workers, that is $n_d(n,x;\varepsilon,a)$ and $u(x)$, and a stationary distribution of firms $f_d(n,x;\varepsilon,a)$; (vi) aggregate technology; and (vii) fiscal surplus FS and lump-sum transfer T, satisfying the following conditions:*

(i) *$m(x)$, $\boldsymbol{v}(x)$, $N(x)$, $\theta(x)$, $f(x)$ and $q(x)$ are the solutions of the matching function (29), the number of vacancies (51), employment (50), the job-finding rate (30), the vacancy-filling rate (31) and the tightness (32), respectively;*

(ii) *The value functions $\Pi(n,x;\varepsilon,a)$ and Π_0 solve jointly the system formed by the recursive equations (34) and (36);*

(iii) *The firms' decision rules $\{\mathcal{D}(n,x;\varepsilon,a), \mathcal{D}_R(n,x;\varepsilon,a)\}$ (incumbent firms), and $\{\mathcal{D}_0, \mathcal{D}_{0,R}\}$ (new firms), are solutions to problems (34) and (36), respectively;*

(iv) *e, $\vartheta(x)$ and $\omega(n;\varepsilon,a|x)$ satisfy (38), (44) and (45);*

(v) *The stationary distribution of (employed and unemployed) workers, that is $\{n_d(n,x;\varepsilon,a), u(x)\}$, solves (46) and (47), and satisfies condition (48). The distribution of firms $f_d(n,x;\varepsilon,a)$ is derived from equation (43);*

(vi) *Aggregate technology solves equation (52);*

(vii) *FS and T satisfy the government budget constraint defined by (53) and (54).*

4 Quantitative analysis

4.1 Functional forms

- As in Elsby and Michaels (2013), idiosyncratic productivity evolves according to the following process:

$$\varepsilon' = \begin{cases} \tilde{\varepsilon} \sim G_0(\tilde{\varepsilon}) & \text{with probability} \quad \lambda \\ \varepsilon & \text{with probability} \quad 1-\lambda \end{cases}$$

  where G_0 is the following truncated Pareto distribution:

$$G_0(\tilde{\varepsilon}) = \frac{1-\left(\frac{\varepsilon}{\tilde{\varepsilon}}\right)^d}{1-\left(\frac{\varepsilon}{\bar{\varepsilon}}\right)^d}.$$

- We assume that unemployed workers and vacancies are matched according to the following matching function:

$$m(u(x), \boldsymbol{v}(x)) = \chi(x) u(x)^{\rho} \boldsymbol{v}(x)^{1-\rho},$$

  where $\chi(x)$ denotes matching efficiency in submarket x and ρ is the elasticity of the matching function with respect to unemployment.

- The operating cost function depends linearly on the technology level:

$$c_o(x) = Kx.$$

- The probability of a technology improvement depends on firm-level R&D investment and aggregate technology $\bar{x}$:

$$p(R, \bar{x}) = 1 - \exp(-\phi R - \psi \bar{x}),$$

  where ϕ and ψ govern the sensitivity of the technology-improvement probability to firm-level R&D investment and aggregate technology, respectively.

- Taxes, R&D tax credits, and fraud detection

$$\begin{aligned} \tau(B) &= \max\{\underline{\tau}B, \overline{\tau}B + (\underline{\tau} - \overline{\tau})\bar{B}\} \\ C(R+s) &= \min\{\kappa_1(R+s), \kappa_2(R+s) + (\kappa_1 - \kappa_2)\bar{R}\} \\ h(s) &= \left(\frac{s}{\bar{s}}\right)^{\zeta} \end{aligned}$$

$\tau(B)$ is the corporate tax rate. Under the French system, firms whose taxable profit B is below the threshold $\bar{B}$ are taxed at the reduced rate $\underline{\tau}$.[15] Taxable profits up to the threshold $\bar{B}$ are taxed at the reduced rate $\underline{\tau}$, while taxable profits above the threshold are subject to the higher marginal rate $\overline{\tau}$. The same structure applies to the R&D tax credit. Reported R&D expenditures up to the threshold $\bar{R}$ are subsidized at rate κ_1, while expenditures above $\bar{R}$ are subsidized at the marginal rate κ_2.

4.2 Calibration and estimation

The model is calibrated and estimated using French data. We calibrate some parameters using external information and estimate the remaining parameters by simulated method of moments. The Online Appendix provides the full solution and estimation procedure. The state space contains $N+1 = 201$ non-equally spaced grid points between 0 and 1, with $\mathcal{N} = \{n_0, \ldots, n_N\}$, $n_0 = 0$, and $n_N = 1$. Because the vast majority of firms are small, we place more grid points at the lower end of the employment grid. We use $n_\varepsilon = 10$ grid points to discretize the idiosyncratic productivity process and $X = 5$ technology levels to generate sufficient heterogeneity while keeping the numerical solution tractable. We consider a quarterly life cycle, with the terminal age state corresponding to firms aged 11 years or more, which implies $n_a = 45$ age states. Firms may survive beyond 11 years, since the terminal age state $a = A$ is absorbing. Firms optimally choose R&D expenditures. We discretize R on a grid of ten equally spaced points over the support $[0, \tilde{R}]$. We choose $\tilde{R}$ sufficiently large that the optimal R&D choice never reaches the upper bound of the grid.

4.2.1 Calibrated parameters

Labor market. The quarterly discount factor β is set to 0.99, implying an annual interest rate of approximately 4%. The exogenous firm-destruction probability δ is set to 1.5% on a quarterly

[15] Eligibility for the reduced corporate tax rate depends on two conditions: taxable profits must be below 42,500 euros and turnover must be below 10 million euros. To simplify the solution and the quantitative analysis, we impose only the taxable-profit condition. We verify ex post that the share of firms benefiting from the reduced rate remains similar when both eligibility conditions are imposed.

basis, corresponding to an annualized exogenous destruction probability of about 6%. As is standard in the search-and-matching literature, the elasticity of the matching function with respect to unemployment, ρ, is set to 0.5. We set the vacancy-filling probability $q(x)$ to 71%, as in Den Haan et al. (2000). Since we are agnostic about how the vacancy-filling probability varies across technology levels, we impose $q(x) = 0.71$ for all x. The matching-efficiency parameters $\chi(x)$ are then chosen so that the equilibrium matching conditions are consistent with these vacancy-filling probabilities. The entry cost c_e is chosen such that the entry condition (38) binds in the benchmark equilibrium. The total mass of firms is normalized to one. Given that $\Pi_0 = c_e$ in the benchmark equilibrium, η_0 is pinned down to achieve this normalization.

Labor market institutions. We set the firing cost parameter c_d to 0.5, which corresponds to six months of the average wage. Bentolila and Bertola (1990) calibrate firing costs for a set of European countries, with values ranging from two months of wages for the United Kingdom in the 1960s to 13 months in Italy in the 1970s. Using French data for the 1990s, Kramarz and Michaud (2010) estimate firing costs of around two months of wages for individual layoffs and six months for collective layoffs. In France, the statutory notice period is two months for workers with at least two years of tenure, although collective agreements may provide different provisions depending on the worker's occupational category. Statutory severance pay amounts to one fourth of a monthly salary per year of tenure for the first ten years and one third thereafter. We set non-employment benefits to 25%, a value below the unemployment-insurance replacement rate in France, reflecting the fact that the model considers non-employment rather than unemployment. Not all non-employed workers receive unemployment benefits.

Corporate taxation and R&D tax credit. The reduced corporate tax rate is $\underline{\tau} = 15\%$, while the standard rate is $\overline{\tau} = 25\%$. Firms are eligible for the reduced corporate tax rate only if their taxable profits are below 42,500 euros. Since profits are expressed in model units, the corresponding threshold $\bar{B}$ is estimated to match the median corporate tax rate observed in the data.

For the R&D tax credit, $\kappa_1 = 30\%$ applies to eligible R&D expenditures up to the statutory threshold of 100 million euros. Above this threshold, the marginal tax-credit rate falls to $\kappa_2 = 5\%$. Since R&D expenditures are expressed in model units, the corresponding threshold $\bar{R}$ is estimated to match the proportion of firms reporting R&D expenditures above 100 million euros.

Fraud and monitoring. We mainly follow Bach et al. (2021) to calibrate the parameters governing fraud and the monitoring of the tax credit. According to the authors, around 4% of firms

receiving the tax credit were audited each year between 2008 and 2018. Because an audit can cover claims filed over the previous three fiscal years, a given claim remains exposed to an audit for three years. In the model, p_a is thus the probability that a given tax-credit claim is audited, rather than the annual audit rate. An audit does not necessarily lead to a sanction: the administration must establish that part of the reported expenditures is ineligible, which is more likely when the misreported amount is large. This is captured by the detection function $h(s)$, so that misreporting is detected and sanctioned with probability $p_a h(s)$. According to Cour des comptes (2013), around 3.6% of firms claiming the CIR have part of their declared expenditures reassessed by the tax administration following an audit. Three quarters of these reassessments occur during audits that were not initially targeted specifically at the CIR, suggesting that, in most cases, firms were not selected ex ante because of suspected CIR-related irregularities. In 2011, the share of CIR claimants subject to a CIR-specific audit was 1.7%. Finally, the amount of expenditures reassessed by the tax administration represented around 2% of total declared R&D expenditures in 2011. To avoid tracking the history of fraud over 3 years (which amounts to 12 lags in our model calibrated at quarterly frequencies) we simply estimate p_a.

In case of proven fraud, the firm must repay the tax credit unduly received on non-R&D expenditures and pay an additional penalty proportional to the amount concerned. The penalty rate varies between 10% and 80%, excluding interest charges.[16] A 10% penalty applies in cases of late correction or irregularities without deliberate misconduct. A 40% penalty applies in cases of deliberate misconduct, that is, when the firm knowingly declares ineligible expenditures. An 80% penalty applies in cases of fraudulent practices, *i.e.*, false invoices, fictitious projects or firms, or forged documents. Since we have limited information on the distribution of penalty rates across firms, we set $\tau_f = 20\%$ in the benchmark calibration and treat it as a policy instrument in Section 5.

The calibrated parameters are reported in Table 1.

[16] In case of proven fraud, the fiscal authority determines the amount of ineligible R&D expenditures over the previous three years. Interest charges therefore depend on the fiscal year in which the expenditures were declared.

Table 1: CALIBRATED PARAMETERS

Parameter	Symbol	Value
Discount factor	β	0.99
Exogenous firm destruction probability	δ	0.015
Matching-function elasticity w.r.t. unemployment	ρ	0.50
Matching efficiency by technology level	$\chi(x)$	[0.38, 0.82, 0.27, 0.10, 0.06]
Entry cost	c_e	0.037
Entry function scale parameter	η_0	0.015
Firing cost parameter	c_d	0.50
Non-employment benefit replacement rate	ρ_R	0.25
Reduced corporate tax rate	$\underline{\tau}$	0.15
Standard corporate tax rate	$\overline{\tau}$	0.25
R&D tax-credit rate below threshold	κ_1	0.30
R&D tax-credit rate above threshold	κ_2	0.05
Fraud penalty rate	τ_f	0.20

4.2.2 Estimated parameters

There are 19 parameters remaining to be estimated:

$$\Theta = \{\gamma, \xi, \underline{x}, \overline{x}, \underline{\varepsilon}, \overline{\varepsilon}, d, \lambda, \alpha, \iota, K, \eta_1, \phi, \psi, \mu, \zeta, p_a, \bar{B}, \bar{R}\}.$$

The empirical moments used in the estimation are the following:

(A) The distribution of firms, employment, and output by firm size;

(B) The distribution of firms by age;

(C) The distribution of R&D expenditures, the number of firms claiming the tax credit, and the tax-credit amount by firm size and age;

(D) Aggregate moments: the median corporate tax rate, the share of firms reporting R&D expenditures above 100 million euros, the share of the total tax credit received by these firms, and the spillover effect.

For moments (A), we use four firm-size groups ($<$ 10, 10–249, 250–4,999, and 5,000+ employees). For moments (B), we use 11 age groups. For moments (C), we use three firm-size groups ($<$ 250, 250–4,999, and 5,000+ employees) and two age groups (0–2 years and more than 2 years). In total, we target 42 moments.

The estimation procedure consists of finding the parameter vector Θ that minimizes the distance between the simulated moments $\mathcal{M}^m(\Theta)$ and the empirical moments $\mathcal{M}^d$. Let $\boldsymbol{W}$

denote the weighting matrix. The SMM estimator $\hat{\Theta}$ solves:

$$\hat{\Theta} \quad = \quad \arg\min_{\Theta} \left[\mathcal{M}^m(\Theta) - \mathcal{M}^d\right]' \mathbf{W} \left[\mathcal{M}^m(\Theta) - \mathcal{M}^d\right]$$

The estimated parameters are reported in Table 2. The wage curvature with respect to productivity is estimated at $\gamma = 0.18$. Although this value is relatively low, it allows highly productive firms to earn substantial profits and grow to large employment levels. The estimated supports of technology x and idiosyncratic productivity ε are sufficiently wide to generate substantial firm-size dispersion. The implied P90/P10 productivity ratio is around two. The Pareto parameter $d = 2.37$ generates a right-skewed distribution of idiosyncratic productivity, which helps replicate the observed firm-size distribution. The estimated value of α assigns approximately equal weights to employment and technology in the production function. The implied elasticity of substitution is 0.84. The estimated operating-cost parameter is $K = 0.03$. Given $c_o(x) = Kx$, total operating costs are Kxn and represent, on average, 2.5% of firm output. The parameter governing entry frictions is estimated at $\eta_1 = 0.01$, implying a weak response of firm entry and therefore relatively strong entry frictions. The probability of technology depreciation is estimated at $\mu = 7.2\%$ per quarter. Abstracting from technology improvements, this corresponds to an expected duration of approximately 3.5 years before depreciation. Ma (2025) constructs a measure of firms' technological obsolescence based on the decline in citations to the knowledge base underlying their patents and estimates an average annual obsolescence rate of 4-7%. While their measure is not directly comparable to our depreciation probability, Jaffe and Trajtenberg (1996) find that patent citations start declining after approximately three to four years, which is broadly consistent with the time scale implied by our estimate. The parameters governing technology improvements are estimated at $\phi = 1.44$ and $\psi = 0.01$. Given the stationary firm distribution, the model implies an average annual probability of technology improvement of 4.37%. We obtain $\zeta = 5.35$ and $p_a = 0.45$ implying a strongly convex fraud-detection function to match the observed detection probability of approximately 20%. Lastly, the taxable-profit threshold used to replicate the median corporate tax rate is estimated at $\bar{B} = 0.002$. The R&D-expenditure threshold is estimated at $\bar{R} = 0.78$. Their ratio is therefore $\bar{B}/\bar{R} = 0.25\%$, compared with $42{,}500/100{,}000{,}000 = 0.043\%$ in the data.

Table 2: ESTIMATED PARAMETERS

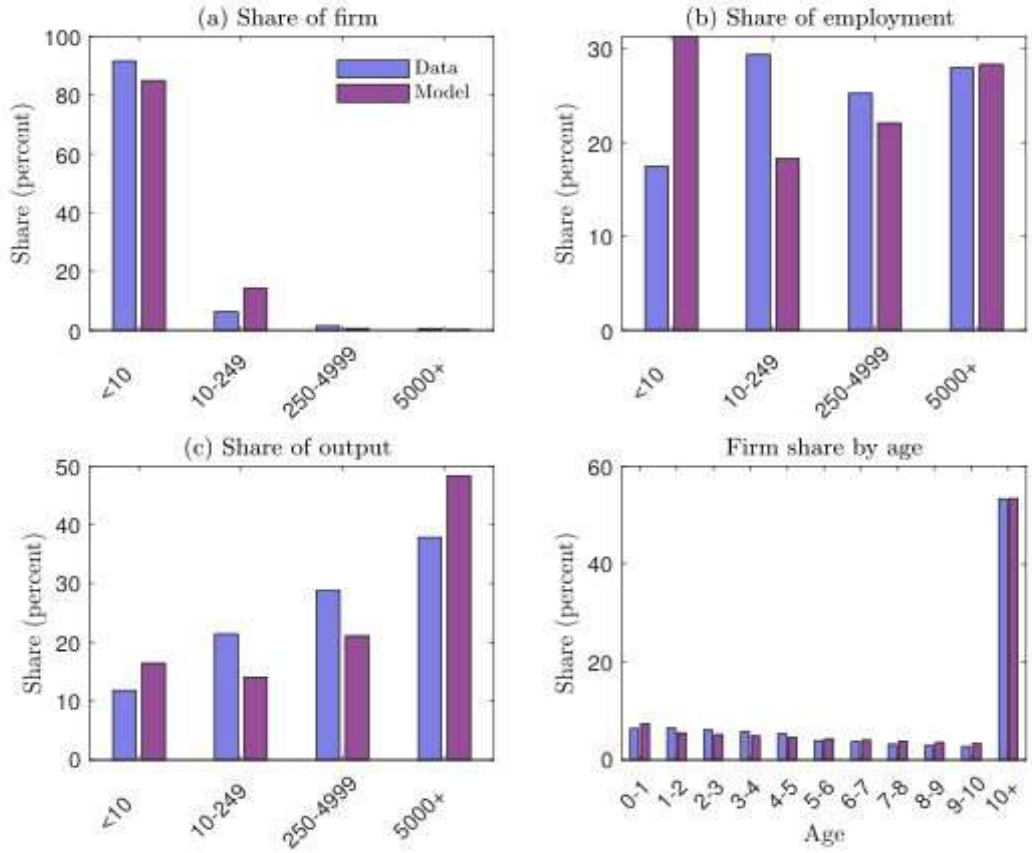
Parameter	Symbol	Value
Wage curvature	γ	0.18
Wage scale	ξ	0.58
Technology support	$[\underline{x}, \overline{x}]$	[0.18,2.51]
Idiosyncratic productivity support	$[\underline{\varepsilon}, \overline{\varepsilon}]$	[0.06,2.21]
Pareto distribution parameter	d	2.37
Productivity shock persistence	λ	0.13
Share of labor in production	α	0.51
CES elasticity parameter	ι	-0.19
Operating cost	K	0.03
Entry sensitivity	η_1	0.01
Probability of technology improvement	ϕ	1.44
R&D spillover parameter	ψ	0.01
Technology depreciation probability	μ	0.072
Fraud detection parameter	ζ	5.35
Audit probability	p_a	0.45
Taxable-profit threshold ($\times 100$)	$\bar{B}$	0.2
R&D-expenditure threshold	$\bar{R}$	0.78

4.2.3 Model fit

We assess the ability of the model to replicate key statistics observed in the data. Figure 4 shows that the model captures the broad shape of the firm-size distribution well (Panel a). The vast majority of firms are small: around 90% have fewer than 10 employees, while 6% have between 10 and 249 employees.[17] Intermediate-sized firms (250–4,999 employees) account for around 1.5% of firms, while large firms (5,000 employees or more) represent around 0.5%. The model also reproduces relatively well the distribution of employment across firm-size groups (Panel b). Although firms with fewer than 10 employees account for the largest share of firms, they represent only 17% of employment. Employment is distributed relatively evenly across the remaining size categories. The model slightly overestimates employment in firms with fewer than 10 employees and understates employment in firms with 10–249 employees by a similar amount. The model also reproduces fairly well the increasing share of output accounted for by larger firms (Panel c). Finally, the model closely matches the observed firm-age distribution (Panel d).

[17] In the French firm-size classification, small and medium-sized enterprises (SMEs) have fewer than 250 employees.

Figure 4: MODEL FIT: FIRM SIZE, EMPLOYMENT, OUTPUT, AND FIRM AGE

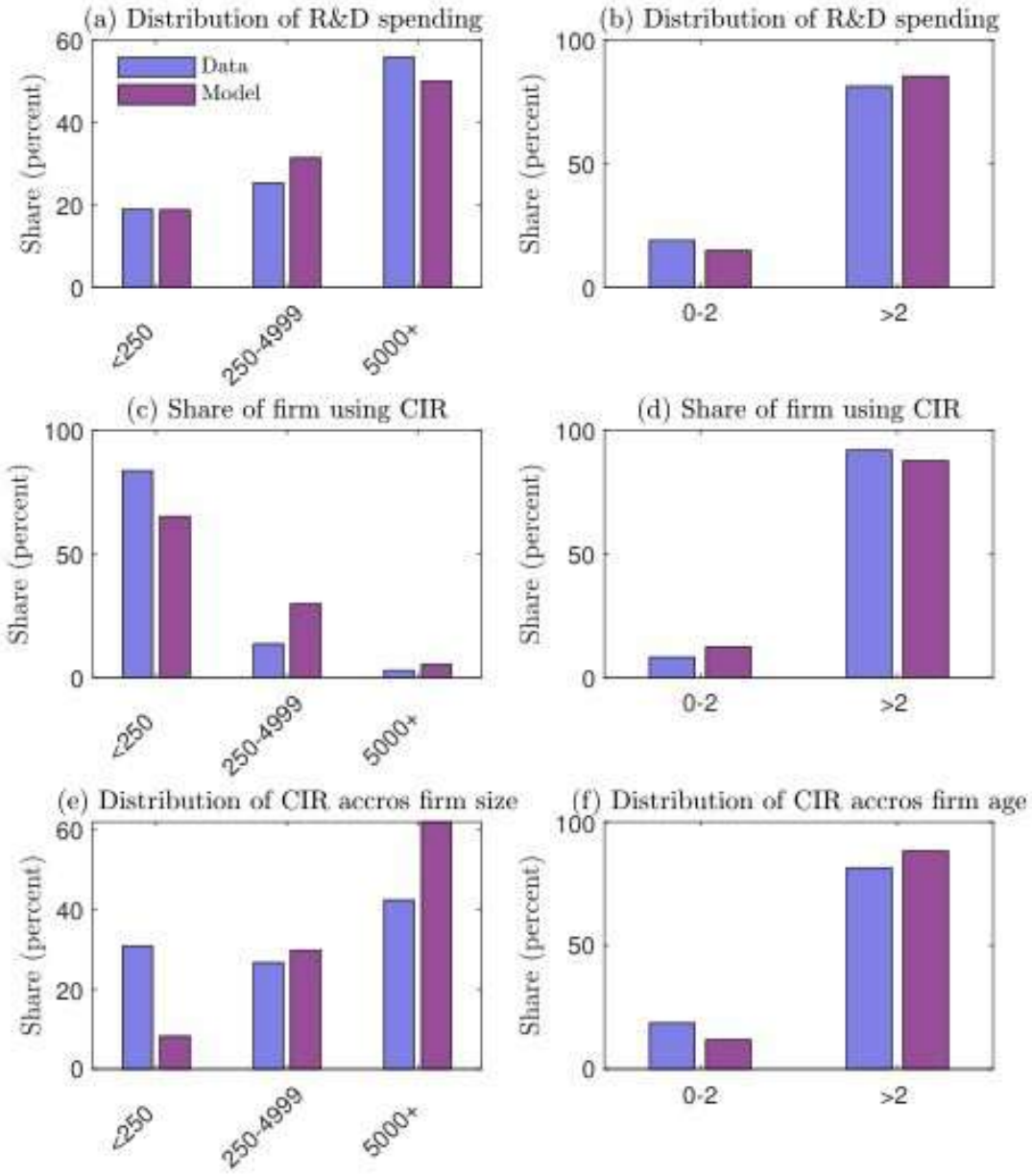


Notes: Bars report the empirical moments and their model counterparts. Firm size is measured by employment. Firm age is measured in years. All panels report shares in percent. See Appendix C for data sources.

We next assess the model's ability to match moments related to R&D and the tax credit. Figure 5 shows that the share of aggregate R&D spending accounted for by large firms is substantially higher than that accounted for by small firms (Panel a), a pattern well reproduced by the model. The model also captures the large share of small firms among tax-credit participants (Panel c), reflecting the underlying firm-size distribution. By contrast, small firms account for a relatively small share of total tax-credit amounts (Panel e), consistent with their limited share of aggregate R&D spending. The model somewhat understates the share of tax-credit amounts received by small firms and overstates that received by large firms. Panels b, d, and f show that firms aged two years or less account for 19% of total R&D spending, 8% of tax-credit participants, and 19% of total tax-credit amounts. Since these firms represent 13% of all firms (Panel d of Figure 4), they account for disproportionately large shares of R&D spending and tax-credit amounts relative to their population share, despite being underrepresented among tax-credit participants. Overall, the model reproduces the main qualitative patterns by firm age and size,

although it understates the share of tax-credit amounts received by small and young firms.

Figure 5: MODEL FIT: R&D SPENDING AND R&D TAX CREDIT



Notes: Bars report the empirical moments and their model counterparts. Firm size is measured by employment and firm age in years. Tax-credit participants are firms receiving a positive tax credit. Tax-credit amounts are reported as shares of the aggregate tax-credit amount. All panels report shares in percent. See Appendix C for data sources.

Table 3 shows that the model reproduces the main aggregate moments reasonably well. It exactly matches the median corporate tax rate of 15%. The share of firms reporting R&D expenditures above 100 million euros is very small in both the model and the data (0.04% in the model versus 0.18% in the data). In the data, 0.51% of firms claim the tax credit, compared

with 0.25% in the model.

Conditional on an audit, 19.2% of claims are found to be non-compliant in the data. The model predicts a corresponding rate of 25.7%. This moment captures the frequency with which misreporting is detected, rather than the extent of relabeling. We measure the latter by the share of non-R&D expenditures in total declared R&D. This second indicator is not targeted in the estimation and is reported in Section 5.

Lastly, the literature provides a range of estimates for the magnitude of technology spillovers, corresponding to output effects between 5% and 20%. Given the uncertainty surrounding these estimates, we target a benchmark value of around 10%. More precisely, we choose ψ so that shutting down the spillover channel ($\psi = 0$) reduces steady-state output by approximately 10%.[18]

Table 3: ADDITIONAL MOMENTS

Target	Model	Data
Median corporate tax rate	15.0	15.0
Firms with R&D expenditures above 100 million (%)	0.04	0.18
Firms receiving the tax credit (%)	0.25	0.51
Share of tax credit above 100 million	26.2	26.0
Fraud detection rate conditional on audit (%)	25.7	19.2
Spillover effect (%)	9.8	[5.0,20.0]

Notes: See Appendix C for data sources.

5 Simulations

In this section, we conduct two quantitative exercises to assess the effects and optimal design of the R&D tax credit. First, we analyze the effects of changes in the tax-credit rate κ_1. Second, we solve numerically for the tax-credit schedule that maximizes aggregate welfare. For clarity, we present the main simulation results in the core of the paper and report additional exercises in the Online Appendix.

5.1 Effects of changes in the tax credit

Our objective is to analyze how firms respond to changes in the tax credit in the short and long run. Starting from the benchmark economy with $\kappa_1 = 30\%$, we consider unanticipated and permanent changes in κ_1 to values ranging from 10% to 50%, that is, changes of up to 20

[18] This output effect incorporates all endogenous adjustments in firms' and workers' decisions, as well as the associated general-equilibrium effects in the new steady state.

percentage points, or two-thirds of its benchmark value, in either direction.[19] To characterize transitional dynamics, we use Monte Carlo simulations in which we draw alternative values of κ_1 from a uniform distribution over this range and compute the resulting trajectories of R&D and employment (Figure 6). We then compare steady states across the same range of values of κ_1 (Figure 7).

Short-run effects For the analysis of transitional dynamics, we draw alternative tax-credit rates from $\tilde{\kappa}_1 \sim U[\kappa_1(1-2/3), \kappa_1(1+2/3)]$ and, for each draw, simulate the transition path following an unanticipated permanent change in κ_1. We compute the trajectories of genuine R&D expenditures, declared R&D expenditures, and employment. At each horizon, Figure 6 reports the mean response across simulated trajectories together with the central 50%, 80%, and 90% simulation bands.

We distinguish between two R&D multipliers. The *real* R&D multiplier is defined as the change in genuine R&D expenditures relative to the benchmark divided by the corresponding change in the tax-credit amount. The *declared* R&D multiplier additionally includes non-R&D expenditures reported as eligible R&D. Panel (a) shows that, for each additional euro of tax credit, genuine R&D expenditures increase on average by around 0.85 euro on impact. The real R&D multiplier declines slightly in subsequent periods and stabilizes at around 0.7 after three years. The declared R&D multiplier reaches around 1.3 on impact and gradually increases to about 1.5 in the long run.

These results are broadly consistent with the main French empirical literature, which generally finds CIR-induced R&D multipliers in the range of roughly 0.5 to 2 additional euros of private R&D per euro of fiscal cost, depending on the methodology. Estimates range from about 0.7 in Mulkay and Mairesse (2013), based on *ex ante* structural-model evaluations, to roughly 0.9 in Mulkay and Mairesse (2018), using *ex post* structural equations, while causal treatment-based econometric studies such as Duguet (2012) and Bach et al. (2021) often report larger effects, with implied multipliers ranging from around 1 to 2. Our analysis, however, highlights the discrepancy between declared expenditures and genuine R&D. The simulations imply that, in the long run, about 50% of the increase in reported R&D reflects the relabeling of non-R&D expenditures rather than additional genuine R&D.

The right-hand plot of Panel (a) reports the employment elasticity with respect to the tax-credit amount. A 1% increase in the aggregate tax credit raises employment by around 0.1% in the short run and by approximately 0.15–0.17% in the long run. This estimate is broadly con-

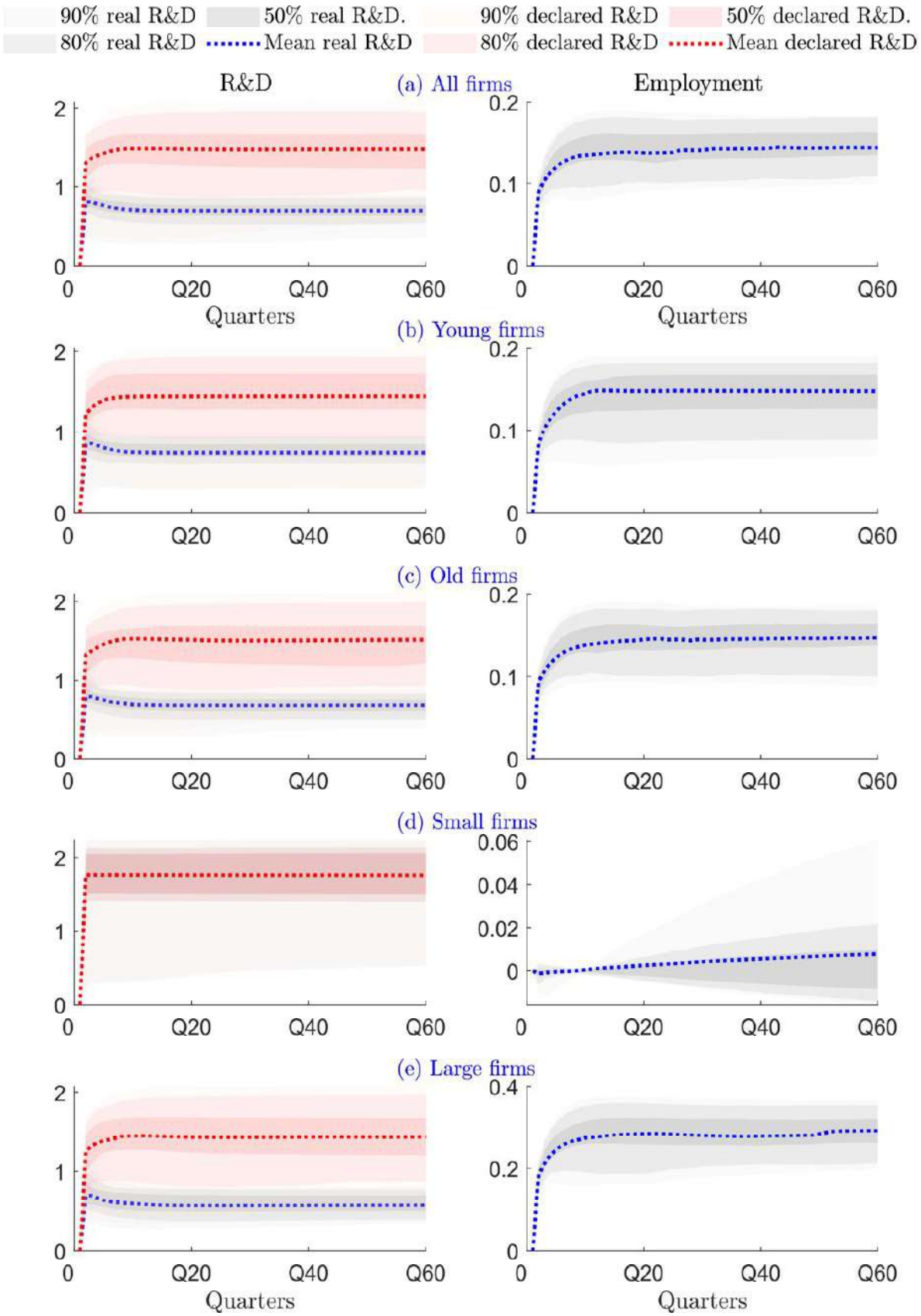
[19] As the share of firms reporting R&D expenditures above 100 million euros is small, we only consider variations in κ_1.

sistent with Bunel and Hadjibeyli (2022), who evaluate the causal effects of the French Crédit d'Impôt Innovation (CII) on several firm-level outcomes. The CII targets small and medium-sized firms and subsidizes innovation-related expenditures (particularly prototype and pilot-plant development) that, while not strictly classified as R&D, are closely related to downstream innovative activity. Using a difference-in-differences approach with propensity-score matching, their estimates imply that, when scaled by the effective CII subsidy rate, the medium-term employment response over roughly three years corresponds to an implied employment elasticity of approximately 0.22.

Panels (b) and (c) report the responses by firm age. We define young firms as firms aged two years or less. The real R&D multiplier is slightly higher for young firms, at around 0.87 on impact and 0.75 in the long run, than for older firms, at around 0.8 on impact and 0.7 in the long run. The declared R&D multiplier is, however, very similar across the two age groups. Employment elasticities are also very similar for young and older firms.

Panels (d) and (e) report the responses by firm size. We define small firms as those with fewer than 250 employees and large firms as those with 250 employees or more. The differences are substantial. For small firms, the real and declared R&D multipliers are virtually identical, whereas a sizeable gap emerges for large firms. The real R&D multiplier is also considerably larger for small firms than for large firms. The declared multiplier is likewise somewhat larger for small firms, although the difference is much smaller. By contrast, the employment response is concentrated among large firms: a 1% increase in the aggregate tax credit raises their employment by around 0.2% on impact and almost 0.3% in the long run. Employment in small firms remains virtually unchanged. Overall, small firms respond to changes in tax-credit generosity primarily by adjusting R&D expenditures, whereas large firms adjust employment much more strongly. These results are consistent with the empirical literature showing larger R&D multipliers for small firms.

Figure 6: R&D MULTIPLIERS AND EMPLOYMENT ELASTICITIES



Notes: Responses to unanticipated permanent changes in κ_1 drawn from $\tilde{\kappa}_1 \sim U[\kappa_1(1-2/3), \kappa_1(1+2/3)]$, with benchmark $\kappa_1 = 30\%$. The real R&D multiplier is $(R_t - R_0)/(C_t - C_0)$, where R_t and C_t denote aggregate genuine R&D expenditures and the aggregate tax-credit amount at time t. The declared R&D multiplier is $(R_t + s_t - R_0 - s_0)/(C_t - C_0)$ and includes misreported non-R&D expenditures. The employment elasticity is $(N_t - N_0)/N_0 \times C_0/(C_t - C_0)$. Dotted lines report means across simulated trajectories; shaded areas report the central 50%, 80%, and 90% of their distribution at each horizon.

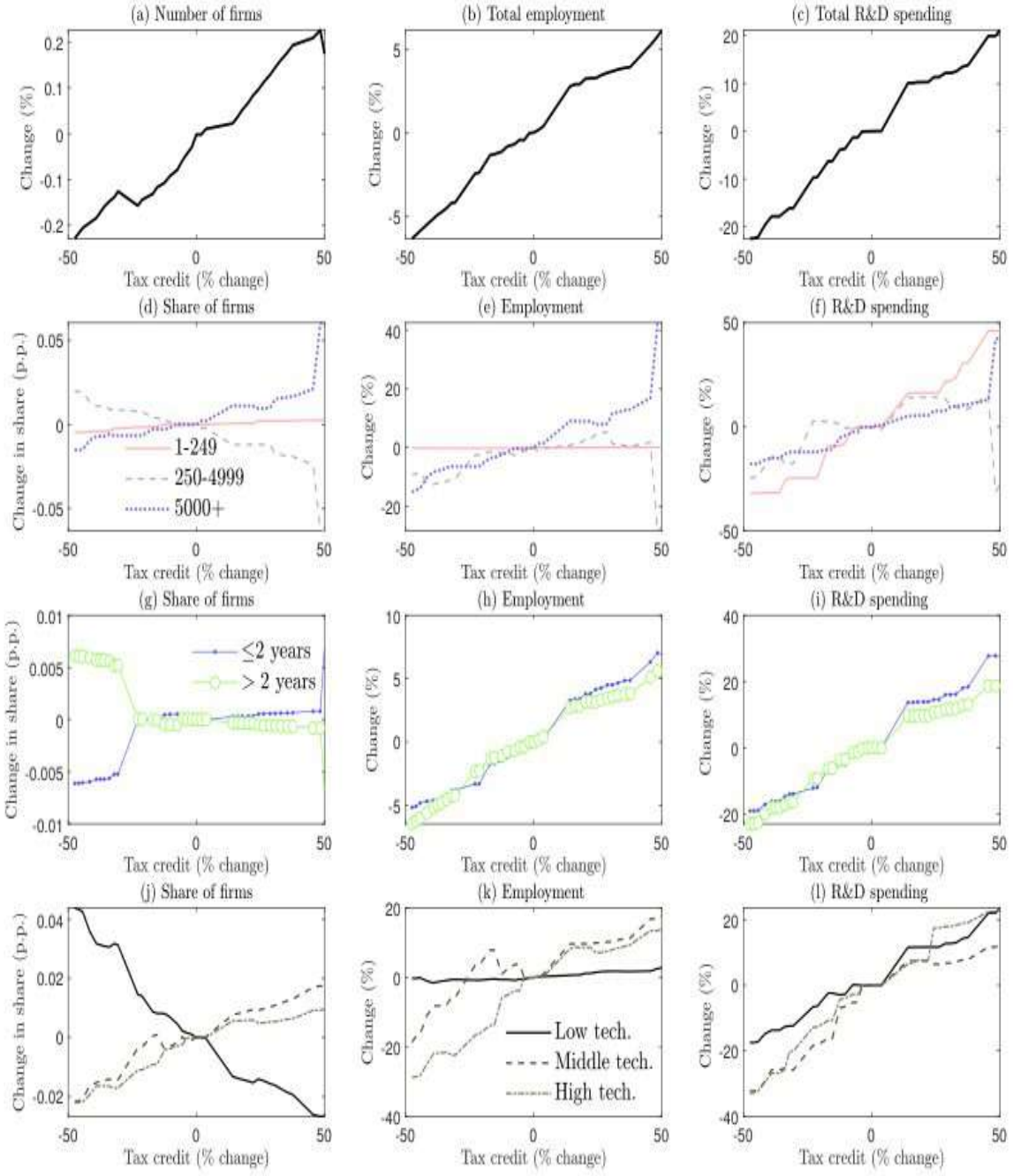
Long-run effects Figure 7 reports the steady-state effects of changes in κ_1, expressed on the horizontal axis in terms of the implied percentage change in the aggregate tax-credit amount relative to the benchmark. Panels (a)–(c) show that a 50% increase in the aggregate tax credit is associated with approximately a 0.2% increase in the number of firms, a 6% increase in employment, and a 20% increase in genuine R&D expenditures.

The decomposition by firm size in Panels (d)–(f) reveals substantial compositional effects. As the tax credit increases, the firm-size distribution shifts toward the largest firms: the share of firms with 5,000 employees or more increases, while the share of intermediate-sized firms declines. Employment gains are also concentrated among larger firms, whereas employment in intermediate-sized firms declines when the tax credit is reduced. R&D expenditures, by contrast, are more responsive to changes in the tax credit among small firms, consistent with the short-run multiplier results.

Panels (g)–(i) report the long-run responses by firm age. An increase in the tax credit raises the share of young firms. Employment responses are very similar across young and older firms, consistent with the employment elasticities reported in Figure 6. By contrast, R&D expenditures respond more strongly among young firms.

Finally, Panels (j)–(l) decompose the long-run responses by technology level. The share of middle- and high-technology firms increases with the tax credit, while the share of low-technology firms declines. Employment responds only weakly among low-technology firms but increases substantially among middle- and high-technology firms. Taken together, Panels (j) and (k) show that an increase in the tax credit shifts the composition of both firms and employment toward higher technology levels. By contrast, R&D responses vary across technology levels and do not follow the same pattern as employment responses. This pattern mirrors the heterogeneity observed across firm-size groups: the firms exhibiting the strongest R&D responses are not those exhibiting the strongest employment responses.

Figure 7: LONG-RUN EFFECTS OF THE R&D TAX CREDIT



Notes: Steady-state effects of changing κ_1, the tax-credit rate applying below 100 million euros, from its benchmark value of 30% to values between 10% and 50%. The horizontal axis reports the implied percentage change in the aggregate tax-credit amount relative to the benchmark, $(C_{\text{new}} - C_{\text{bench}})/C_{\text{bench}} \times 100$. R&D spending corresponds to genuine R&D expenditures and excludes misreported non-R&D expenditures. Firm shares are reported as changes in percentage points; all other variables are reported as percentage changes relative to the benchmark.

5.2 Optimal policy

We investigate the optimal design of the R&D tax credit by determining policy parameters that maximize aggregate welfare. The previous results show that the effects of the tax credit differ across firms of different ages, sizes, and technology levels. We therefore consider both non-contingent and state-dependent tax-credit schedules. In all cases, we impose a fiscal constraint that limits the deterioration in the fiscal surplus relative to the benchmark economy.[20] Our objective is to determine the policy parameters κ_i, $\bar{R}$, $\bar{a}$, and $\bar{n}$ that maximize welfare. Welfare $\mathcal{W}$ is defined as the discounted sum of aggregate consumption under linear utility. Aggregate consumption includes labor income, non-employment benefits, the lump-sum transfer T, and firm profits net of hiring, firing, R&D, and operating costs, as well as the hiring and entry costs incurred by new firms. Appendix B provides the formal definition and derivation of the welfare measure.

Optimal tax credit The optimization problem is defined as follows:

$$\kappa_i^*, \bar{R}^*, \bar{a}^*, \bar{n}^* = \arg\max_{\kappa_i, \bar{R}, \bar{a}, \bar{n}} W(\kappa_i, \bar{R}, \bar{a}, \bar{n}), \tag{55}$$
$$\text{s.t.} \quad FS(\kappa_i, \bar{R}, \bar{a}, \bar{n}) - FS(\kappa^{bench}) \geq -e$$

where $\boldsymbol{\kappa}_{bench} = \{\kappa_1, \kappa_2\}$ denotes the vector of tax-credit rates in the benchmark economy, with $\kappa_1 = 0.30$ and $\kappa_2 = 0.05$. We allow for a limited deterioration in the fiscal surplus to assess whether substantial welfare gains can be achieved at a modest fiscal cost. Specifically, we set the tolerance parameter ϵ to 0.1% of benchmark output. We consider tax credits of the form:

$$C(R) = \max\left[0, \min(\kappa_0(a,n) + \kappa_1(a,n)R, \kappa_2(a,n)R + \kappa_0(a,n) + (\kappa_1(a,n) - \kappa_2(a,n))\bar{R}\right] \tag{56}$$

Equation (56) specifies a parsimonious tax-credit schedule. Although richer specifications with additional parameters and nonlinearities could be considered, we focus on schedules that remain simple, transparent, and easy to implement. This specification generalizes the benchmark schedule, which features two marginal tax-credit rates, κ_1 and κ_2, and an R&D expenditure threshold $\bar{R}$ at which the marginal rate changes.

Consistent with the analytical results derived in Section 2.6.1, we introduce the parameter κ_0 as a constant component of the tax-credit schedule. Its interpretation is nevertheless some-

[20] First, we aim to characterize policy reforms that remain feasible under a fiscal constraint. Second, the benchmark model closes the government budget with lump-sum transfers. Alternative financing instruments, such as labor or capital taxation, are beyond the scope of the paper.

what different here. In Section 2.6.1, κ_0 is a general tax or subsidy used to offset matching frictions and restore efficiency. As such, it corrects labor-market distortions that are not solely related to R&D, and the optimal value of κ_0 may therefore be negative. In the quantitative exercise, by contrast, we restrict attention to non-negative tax credits, *i.e.*, subsidies to firms undertaking R&D, and do not consider taxing firms with zero or low R&D expenditures. We therefore introduce the $\max(\cdot)$ operator in Equation (56). When $\kappa_0 < 0$, firms must undertake a minimal amount of R&D to receive a positive tax credit. This allows us to assess whether introducing a minimum R&D requirement can improve welfare.

We also consider two state-dependent tax-credit schedules in which the parameters of the schedule depend on either firm age or firm size. In each case, the parameters are allowed to differ across two groups of firms, defined by an age threshold $\bar{a}$ or an employment threshold $\bar{n}$, respectively.

$$\kappa_i(a) = \begin{cases} \kappa_{i,y} & \text{if} \quad a < \bar{a} \\ \kappa_{i,o} & \text{if} \quad a \geq \bar{a} \end{cases} \qquad \kappa_i(n) = \begin{cases} \kappa_{i,s} & \text{if} \quad n < \bar{n} \\ \kappa_{i,l} & \text{if} \quad n \geq \bar{n} \end{cases}$$

For $i \in \{0, 1, 2\}$, $\kappa_{i,y}$ and $\kappa_{i,o}$ denote the parameters applying to younger and older firms, respectively, while $\kappa_{i,s}$ and $\kappa_{i,l}$ denote those applying to smaller and larger firms. For simplicity, we restrict the R&D expenditure threshold $\bar{R}$ to be common across groups within each policy. France already has an age-based support scheme for innovative firms, the "Jeune Entreprise Innovante" (JEI) program. Under this program, young firms satisfying eligibility conditions related to age, size, turnover, and R&D activity can benefit from specific tax and social-contribution exemptions. Our age- and size-dependent tax-credit schedules can therefore be viewed as stylized extensions of this type of targeted innovation policy.

As a reference point, we also consider a laissez-faire economy without public intervention. The R&D tax credit is removed, $C(\cdot) = 0$, implying $\kappa_1 = \kappa_2 = 0$ and making the R&D threshold $\bar{R}$ irrelevant. Non-employment benefits are set to zero, $b(x) = 0$, firms are not subject to corporate taxation, $\tau(B) = 0$, implying $\underline{\tau} = \overline{\tau} = 0$, and there is no audit or fraud penalty, $p_a = \tau_f = 0$. Since firms have no incentive to relabel expenditures as R&D, misreporting disappears, $s = 0$.

The optimal tax-credit schedules are depicted in Figure 8, and the corresponding parameter values are reported in Table 4. Panel (a) of Figure 8 displays the non-contingent policies. Policy (A) features a marginal tax-credit rate below the R&D expenditure threshold that remains close to its benchmark value (30.4%), but a substantially lower rate above the threshold (0.6%). Policy (B) also allows the R&D expenditure threshold to adjust. The optimal schedule features a higher marginal rate of 32% below the threshold, a lower rate of 4.2% above it, and a reduction

in the threshold to approximately 77 million euros.

Policy (C) additionally allows for a constant component κ_0. Its optimal value is negative, implying that firms must meet a minimum declared R&D expenditure requirement before receiving a positive tax credit. Above this minimum requirement of approximately 2.5 million euros, the marginal tax-credit rate is 34.1% up to an R&D expenditure threshold of approximately 77 million euros and 5.1% thereafter.

The optimal age-dependent policy, Policy (D) in Panel (b), features similar marginal tax-credit rates for younger and older firms but substantially different minimum R&D expenditure requirements: approximately 3.85 million euros for younger firms and 9 million euros for older firms. The optimal schedule is thus more generous toward younger firms, primarily through a lower minimum expenditure requirement rather than higher marginal tax-credit rates. The optimal age threshold is approximately ten years.

Finally, the optimal size-dependent policy, Policy (E) in Panel (c), features higher marginal tax-credit rates for firms above the employment threshold, which is approximately 17 employees. Below the R&D expenditure threshold, the marginal tax-credit rate is 29.1% for smaller firms and 39.4% for larger firms. Above the R&D expenditure threshold, the corresponding rates are 2% and 5.2%, respectively. The minimum R&D expenditure requirement is also lower for larger firms.

Figure 8: OPTIMAL R&D TAX-CREDIT SCHEDULES

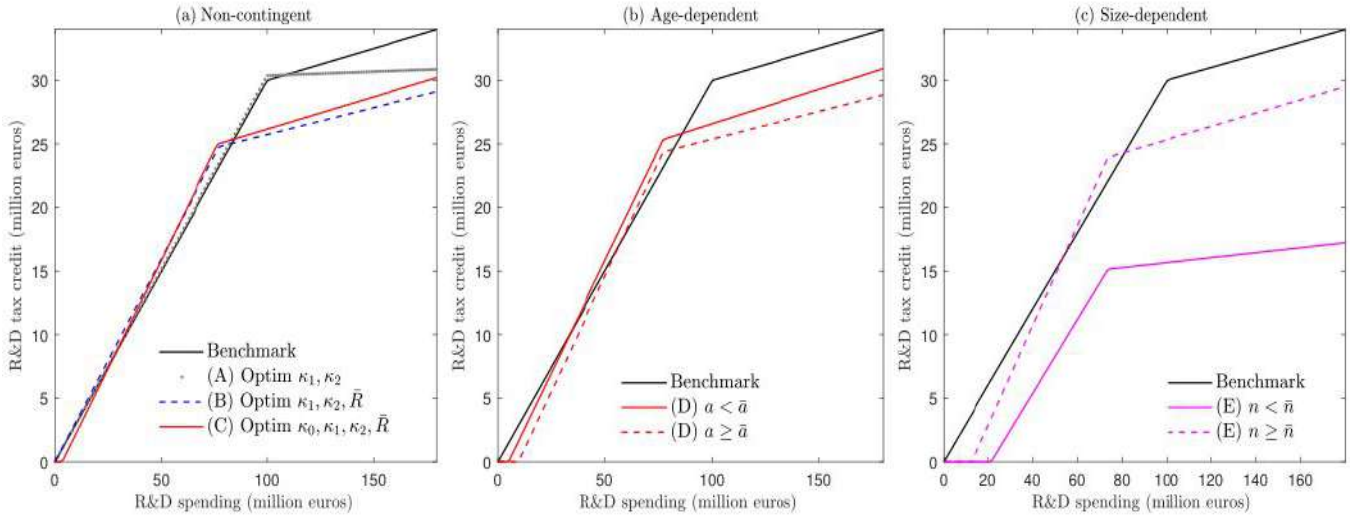


Table 4: CHARACTERISTICS OF THE OPTIMAL POLICIES

Allocation	κ_0 $\times 100$	κ_1 (%)	κ_2 (%)	$\bar{R}$ (million)	$\bar{a}$ years	$\bar{n}$ size
Bench.	-	30.0	5.0	100	-	-
Laissez-faire	-	-	-	-	-	-
(A) Optimal κ_1, κ_2	-	30.4	0.6	100	-	-
(B) Optimal $\kappa_1, \kappa_2, \bar{R}$	-	32.0	4.2	77.4	-	-
(C) Optimal $\kappa_0, \kappa_1, \kappa_2, \bar{R}$	-0.902	34.1	5.1	76.6	-	-
(D) Optimal age-dependent	-1.3	35.0	5.4	77.2	9.9	-
	-2.6	36.0	4.4			-
(E) Optimal size-dependent	-4.9	29.1	2.0	73.6	-	17.2
	-3.9	39.4	5.2		-	

Table 5 reports the aggregate effects of the optimal policies together with those of the laissez-faire economy. The laissez-faire allocation entails a welfare gain of 3.5% relative to the benchmark, while employment, output, and R&D expenditures decrease by approximately 11%, 9%, and 47%, respectively. At the same time, the fiscal surplus-to-output ratio increases by 3.9 percentage points, as the removal of non-employment benefits and the R&D tax credit more than offsets the loss of corporate tax revenue.

Policy (A) yields a modest welfare gain of 0.3%. By contrast, Policy (B), which also optimizes the R&D expenditure threshold, generates a substantial welfare gain of 4%. Employment, output, and genuine R&D expenditures increase by 2.9%, 3.1%, and 2.2%, respectively, while the fiscal surplus remains close to its benchmark level. Despite the lower R&D expenditure threshold, both aggregate R&D expenditures and total tax-credit expenditures increase under the optimal schedule.

Policy (C), which introduces a minimum R&D expenditure requirement through a negative constant component κ_0, further increases the welfare gain to 4.4%. Relative to the benchmark, employment increases by 3.6%, output by 3.4%, and genuine R&D expenditures by 2.2%. The percentage of audits resulting in fraud detection declines by approximately five percentage points. Policies (D) and (E) generate welfare gains while increasing the fiscal surplus relative to the benchmark. Compared with Policy (C), the age-dependent policy (D) delivers virtually the same welfare gain but improves the fiscal surplus. The size-dependent policy (E) generates the largest welfare gain, at 5.2%, while increasing employment by 5.2%, output by 3.9%, and genuine R&D expenditures by 2.5%. These gains come with virtually unchanged tax-credit expenditures and a 0.73 percentage-point increase in the fiscal surplus-to-output ratio.

Table 5: AGGREGATE EFFECTS OF THE OPTIMAL POLICIES

	Bench.	Laissez Faire	Optimal				
			(A)	(B)	(C)	(D)	(E)
Welfare	100.00	103.54	100.30	104.03	104.42	104.43	105.15
$\frac{\text{Fiscal surplus}}{\text{Output}} \times 100$	0.00	3.87	-0.09	-0.00	-0.10	0.25	0.73
Employment	100.00	88.96	100.15	102.89	103.55	103.60	105.23
Output	100.00	91.22	100.07	103.08	103.39	103.36	103.86
R&D	100.00	53.37	99.41	102.24	102.23	102.06	102.47
Perc. audit → fraud	25.7	0.0	25.5	20.8	20.5	20.7	19.4
Credit tax	100.00	0.00	101.29	103.78	105.10	102.73	99.95

All variables, except the fiscal surplus-to-output ratio and the percentage of audits resulting in fraud detection, are expressed as indices, with the benchmark normalized to 100. The fiscal surplus-to-output ratio is reported as a percentage-point deviation from the benchmark (normalized to zero). The share of audits resulting in fraud detection is reported in percent.

Optimal tax credit and fraud penalty We now repeat the previous exercise while treating the fraud penalty τ_f as an additional policy instrument. The optimization problem becomes:

$$\kappa_i^*, \bar{R}^*, \bar{a}^*, \bar{n}^*, \tau_f^* = \arg \max_{\kappa_i, \bar{R}, \bar{a}, \bar{n}, \tau_f} W(\kappa_i, \bar{R}, \bar{a}, \bar{n}, \tau_f), \tag{57}$$

$$\text{s.t.} \quad FS(\kappa_i, \bar{R}, \bar{a}, \bar{n}, \tau_f) - FS(\kappa^{bench}, \tau_f^{bench}) \geq -e$$

The functional form of the tax-credit schedules remains as specified in Equation (56). The optimal policy parameters are reported in Figure 9 and Table 6, while the corresponding aggregate outcomes are reported in Table 7. When the fraud penalty is the only policy instrument, the optimal additional penalty is zero, yielding a welfare gain of 0.6% relative to the benchmark. Firms are nevertheless required to repay any tax credit unduly received when misreporting is detected. Allowing the fraud penalty to be optimized jointly with the tax-credit schedule leaves the main features and the ranking of the alternative policy designs largely unchanged. The optimal penalty rate is lower than its benchmark value under Policies (A) and (B), unchanged under Policies (C) and (D), and slightly higher under Policy (E). The size-dependent schedule continues to generate the largest welfare gain, reaching 5.3%, while increasing employment, output, genuine R&D expenditures, and the fiscal surplus.

Figure 9: OPTIMAL R&D TAX-CREDIT SCHEDULES WITH AN OPTIMIZED FRAUD PENALTY

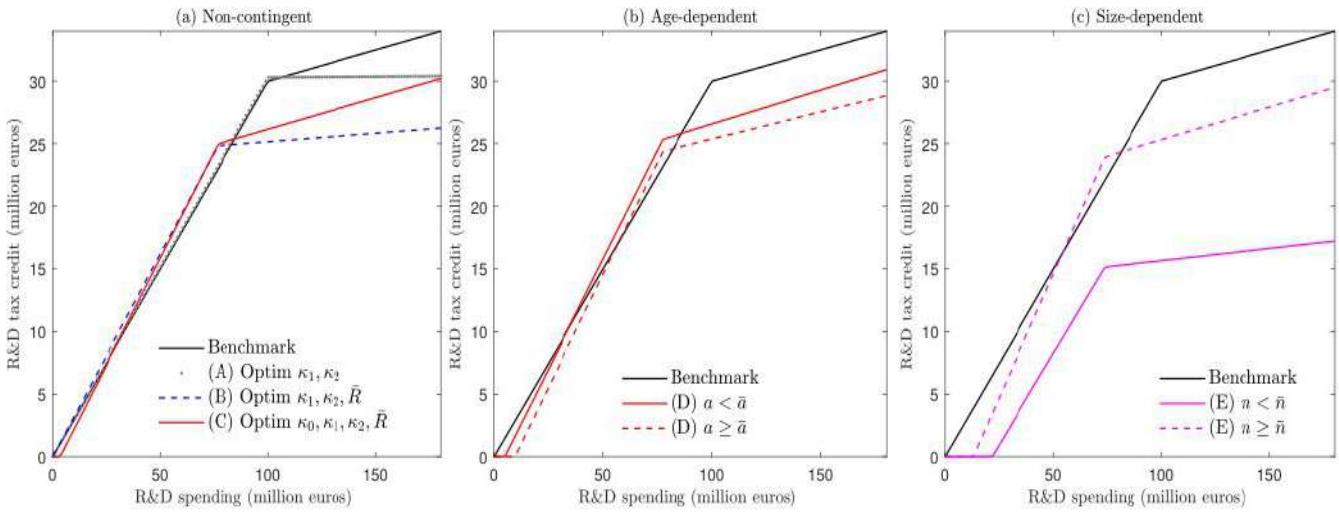


Table 6: CHARACTERISTICS OF THE OPTIMAL POLICIES

Allocation	κ_0 $\times 100$	κ_1 (%)	κ_2 (%)	$\bar{R}$ (million)	$\bar{a}$ years	$\bar{n}$ size	τ_f (%)
Bench.	-	30.0	5.0	100	-	-	20.00
Optimal τ_f	-	30.0	5.0	100	-	-	0.00
(A) Optimal κ_1, κ_2	-	30.3	0.1	100	-	-	6.50
(B) Optimal $\kappa_1, \kappa_2, \bar{R}$	-	32.4	1.4	76.6	-	-	17.79
(C) Optimal $\kappa_0, \kappa_1, \kappa_2, \bar{R}$	-0.902	34.1	5.1	76.6	-	-	20.00
(D) Optimal age-dependent	-1.3	35.0	5.4	77.2	9.9	-	20.00
	-2.6	36.0	4.4			-	
(E) Optimal size-dependent	-4.9	29.1	2.0	73.6	-	17.2	21.17
	-3.9	39.4	5.2		-		

Table 7: AGGREGATE EFFECTS OF THE OPTIMAL POLICIES

	Bench.	Optimal + τ_f					
		τ_f only	(A)	(B)	(C)	(D)	(E)
Welfare	100.00	100.61	100.84	104.10	104.42	104.43	105.34
$\frac{\text{Fiscal surplus}}{\text{Output}} \times 100$	0.00	-0.09	-0.09	-0.08	-0.10	0.25	0.72
Employment	100.00	100.48	100.51	102.99	103.55	103.60	105.41
Output	100.00	100.18	100.19	103.05	103.39	103.36	104.08
R&D	100.00	98.84	98.19	101.77	102.23	102.06	102.88
Perc. audit $\rightarrow$ fraud	25.73	31.15	29.13	20.51	20.52	20.69	18.71
Credit tax	100.00	102.04	102.44	104.55	105.10	102.73	100.04

All variables, except the fiscal surplus-to-output ratio and the percentage of audits resulting in fraud detection, are expressed as indices, with the benchmark normalized to 100. The fiscal surplus-to-output ratio is reported as a percentage-point deviation from the benchmark (normalized to zero). The share of audits resulting in fraud detection is reported in percent.

6 Robustness checks

In this section, we assess the robustness of our results along two dimensions. First, we consider alternative values for the magnitude of R&D spillovers. Second, we examine the sensitivity of the results to the strength of the firm-entry channel. For each alternative calibration, we repeat the simulation exercises presented in Section 5. The results for the tax-credit multipliers and long-run effects are reported in the Online Appendix, while those for optimal policies are available upon request.

6.1 Spillover effects

In the benchmark calibration, the magnitude of the R&D spillover is chosen so that shutting down the spillover channel ($\psi = 0$) reduces steady-state output by approximately 10%. The literature reports a wide range of estimates depending on the measure and methodology used. To assess the sensitivity of our results, we consider two alternative cases: one with no spillovers ($\psi = 0$) and one in which the spillover effect is twice as large as in the benchmark calibration. In the high-spillover calibration, shutting down the spillover channel reduces steady-state output by approximately 20%. This case can be viewed as an upper-bound calibration and is consistent with the estimates reported by Bloom et al. (2013).

Simulations show that stronger spillovers slightly amplify the response of R&D to changes in the tax credit in the short run, as measured by the multipliers, and have more pronounced effects on the long-run responses. The main qualitative results remain unchanged: R&D expenditures respond more strongly among small firms, whereas employment responses are larger among large firms. In addition, the gap between declared and genuine R&D remains of the same order of magnitude across the alternative spillover calibrations.

The optimal policies retain the main features obtained under the benchmark calibration. In all cases, the best-performing non-contingent schedule combines a minimum R&D requirement with a marginal tax-credit rate higher than 30% below an R&D expenditure threshold of approximately 75 million euros. The state-dependent schedules continue to provide more generous tax credits to younger firms and to firms above a size threshold, while the size-dependent schedule generates the largest welfare gains. Whenever the fraud penalty is optimized jointly with the tax-credit schedule, its optimal value may be lower or higher than the benchmark level. Welfare gains from optimal policies are larger in the absence of spillovers, and smaller when spillovers are twice as large as in the benchmark calibration.

6.2 Entry channel

The parameter η_1 governs the sensitivity of firm entry e to the net value of entry, $\Pi_0 - c_e$, and therefore determines the strength of the firm-entry channel. Although η_1 is estimated jointly with the other model parameters, there is no directly comparable empirical estimate that can be used to discipline its value. We therefore assess the robustness of our results to alternative values of η_1.

Specifically, we consider two alternative calibrations in which the entry response is either shut down, $\eta_1 = 0$, or twice as strong as in the benchmark calibration. In the latter case, a 1% increase in tax-credit generosity raises firm entry by approximately 0.005%.

The optimal policies and their aggregate effects remain very close to those obtained under the benchmark calibration, both when the entry channel is shut down and when it is twice as strong. In particular, the main ranking of the policy designs is unchanged, and the maximum welfare gains remain around 5%.

7 Conclusion

This paper studies the effects of R&D tax credits on R&D investment, firm dynamics, and employment, as well as their optimal design when firms can relabel non-R&D expenditures as

R&D. We combine a stylized search-and-matching model with R&D investment, which yields analytical results on the underlying mechanisms, and a quantitative life-cycle model with heterogeneous firms, endogenous entry and exit, and R&D spillovers. We estimate the quantitative model on French data to quantify these mechanisms and to characterize the optimal tax credit.

The toy model provides closed-form results on the channels through which the tax credit operates. The tax credit raises both R&D investment and job creation, and the employment response is proportionally larger among high-technology firms. For a given tax credit, spillovers reduce private R&D investment and create an additional channel through which the tax credit stimulates job creation. The possibility of misreporting non-R&D expenditures as R&D raises the expected value of a vacancy, so that the gain from fraud acts as a subsidy to job creation. Implementing the first best generally requires combining a proportional credit, which corrects the R&D investment distortion and is higher in the presence of spillovers, with a lump-sum component, which corrects the distortion in vacancy creation and is lower when fraud is possible. The R&D tax credit is therefore also a labor-market policy.

The quantitative model reproduces a large set of moments, including the distributions of firms, employment, and output by firm size, the age distribution of firms, and the distributions of R&D spending, tax-credit participants, and tax-credit amounts by firm size and age. R&D responds most strongly among small firms, whereas employment responds most strongly among large and middle- and high-technology firms. The firms exhibiting the strongest R&D responses are therefore not necessarily those exhibiting the strongest employment responses. Our framework also allows firms to relabel non-R&D expenditures as eligible R&D. Although relabeling has been documented empirically, it has received little attention in quantitative models of innovation policy and, to our knowledge, has not been studied in a dynamic general equilibrium model with heterogeneous firms and labor-market frictions. We find that relabeling is sizable. In the long run, each additional euro of tax credit raises declared R&D by about 1.5 euros but genuine R&D by only about 0.7 euro, so that about 50% of the increase in reported R&D reflects relabeled expenditures. Multipliers based on declared expenditures may therefore substantially overstate the amount of genuine R&D generated by the policy.

Turning to policy design, re-optimizing the two statutory rates alone yields only limited welfare gains. Gains arise instead from reshaping the tax-credit schedule and from targeting it. The best-performing non-contingent schedule combines a minimum R&D expenditure requirement with a higher marginal credit rate below a lower R&D expenditure threshold. As in the toy model, allowing for a constant component in the tax-credit schedule provides an addi-

tional policy margin. In the quantitative model, this component is negative and thus introduces a minimum R&D expenditure requirement.

The optimal age-dependent schedule is more generous toward younger firms, primarily through a lower minimum R&D expenditure requirement. By contrast, the optimal size-dependent schedule assigns higher marginal tax-credit rates to firms above an employment threshold of approximately 17 employees. The latter policy yields the largest welfare gain, reaching 5.3% when the fraud penalty is also optimized. Employment, output, and genuine R&D expenditures increase by 5.4%, 4.1%, and 2.9%, respectively, while the fiscal surplus increases and aggregate tax-credit expenditures remain virtually unchanged. These findings highlight the importance of accounting for labor-market effects, in addition to R&D responses, when designing innovation policies. They also provide a quantitative assessment of several reforms proposed in the French debate on the CIR. In particular, optimizing the existing tax-credit schedule yields a lower R&D expenditure threshold and a reduced marginal credit rate above that threshold, consistent with the direction of the reforms advocated by Jaravel (2022) and Aghion (2026). Introducing a minimum R&D expenditure requirement provides an additional policy margin and yields further welfare gains. Allowing the schedule to depend on firm characteristics also improves welfare, although the optimal targeting does not necessarily favor firms with the strongest R&D responses.

Our results show that firm heterogeneity, labor-market frictions, and misreporting all matter for the design of R&D tax incentives. Given the extent of relabeling and the gap between declared and genuine R&D responses, a natural extension would be to compare the current system with an alternative in which the CIR is abolished and the resulting fiscal savings are used to finance a reduction in the corporate income tax rate. Such an exercise would allow us to assess the welfare gains or losses associated with replacing the CIR with an ex ante revenue-equivalent reduction in corporate taxation, while accounting for the resulting changes in R&D investment, employment, and firm dynamics. Future research could also extend the framework to incorporate financial frictions, multiple sectors with different innovation intensities, on-the-job search, and endogenous patenting decisions, in order to provide a more comprehensive assessment of innovation policies and their long-run macroeconomic consequences.

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