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Declining research productivity and income inequality: A centenary perspective ☆

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ABSTRACT

Research productivity has been sharply declining since 1920. This decline has significant implications for inequality. Using an open-economy Schumpeterian growth model, we show that domestic research productivity influences income inequality through two opposing forces: a positive effect from increased asset returns and a negative effect from the erosion of innovation rents through creative destruction. In contrast, foreign research productivity affects inequality solely through the asset returns channel. By constructing a long historical data series for 21 OECD countries, we find that the asset returns channel has been the dominant driver of inequality over the past century. The reduction in both domestic and foreign R&D productivity accounts for 25% to 35% of the observed downward trend in income inequality over this period.

1. Introduction

R&D productivity has been markedly declining since 1920, where R&D productivity is measured by patents relative to the number of R&D researchers or real R&D expenditure. For the US, Bloom et al. (2020) find that research productivity has decreased by more than 5% annually since the 1930s, and Griliches (1994) shows that research productivity has declined by approximately 4.4% annually over the period 1920-1990. According to Schmookler (1954), this trend was evident since the late nineteenth century. The significant decrease in research productivity is not confined to the US but has been observed across the 21-country sample used in this study. Concurrently, income inequality, measured by the top 5% income share or the Gini coefficient, has also markedly decreased over the past century, declining by approximately 25% from 1920 to 2019.

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In this paper, we contend that the downward trend in research productivity may have contributed to the decline in income inequality over the last century. To show this, we extend the open-economy Schumpeterian quality-ladder model by Chu and Cozzi (2018). Our framework predicts that the productivity of domestic research activities has a dual impact on income distribution, operating through two conflicting channels. Ceteris paribus, an increase in domestic research productivity increases the rate of economic growth and the interest rate. This mechanism tends to favor asset-wealthy households, leading to an increase in income inequality (interest-rate channel). Simultaneously, by accelerating the rate of innovation, higher research productivity reduces the market value of incumbent firms through creative destruction. The resulting decrease in the value of financial assets mitigates income inequality (asset-value channel). While the domestic research productivity operates through the above two channels with opposite inequality outcomes, the effect of productivity of research undertaken abroad only operates through the conduit of the interest-rate channel, thus having an unambiguously positive effect on income inequality.

Empirically, we examine the model's predictions using novel data covering over a century for 21 high-income countries. Specifically, we assess the impacts of domestic and foreign research productivity on the Gini coefficient, the top 5% income share, and the factor income ratio using cointegration and local projections (Sections 4-6). The latter procedure is used to perform an event analysis simulating the inequality response to an institutional shock that, by relaxing the patent application process, raised 'measured' research productivity, or the inequality response to an unanticipated shock to R&D productivity. Furthermore, to strengthen our results, we conduct a two-stage regression analysis to isolate the effects of domestic research productivity transmitted through the interest-rate channel and the asset-value channel, while controlling for foreign research productivity (Section 7). The regression results suggest that the interest-rate channel has been more influential in driving inequality than the asset-value channel over the past century. The different approaches used to identify the inequality effects of innovation point to a robust causal effect of research productivity on inequality. According to our most conservative estimates, the yearly decline of 8.5% in domestic R&D productivity and 7.7% decline in foreign R&D productivity from 1920 to 2019 explain between 25% and 35% of the observed downward trend in income inequality over the past century.

We make two principal contributions to the literature. First, the paper is likely the first to examine the inequality effects of research productivity by explicitly identifying the channels through which research productivity influence inequality. Second, the paper is the first to empirically test the inequality effects of domestic and foreign research productivity using long historical panel data. The use of cross-country data in this study stands in contrast to most studies on research productivity, which typically focus on the US (see, e.g., Aghion et al., 2023; Bloom et al., 2020). A significant benefit derived from the use of panel data is its ability to control for common unobserved confounders that vary at the same rate over time across countries. However, we extend this practice by incorporating common correlated effects to capture the impact of global shocks to the innovative environment, such as major macro inventions that stimulate a cascade of micro innovations and create heterogeneous effects across countries. The global nature of innovations, access to technology, and educational resources underscores the importance of addressing endogeneity due to common effects in the regressions. Furthermore, studies using aggregate cross-country data on R&D expenditure and patent statistics have been limited by short coverage periods from official sources. The use of long-term data not only enhances the efficiency of the estimates but also ensures that they are not driven solely by short- or medium-term trends, which are typical features of shorter data spans.

Our research is related to the literature that links innovation to income inequality, which has yielded mixed results (Akcigit et al., 2017). Intellectual property rights, including patenting, tend to favor the appropriation of innovation rents, thereby contributing to increasing income inequality (Lee and Rodríguez-Pose, 2013) and the capital share of national income (Koh et al., 2020; Guellec, 2020). O'Mahony et al. (2021) examine the effect of R&D on the labor share of national income. Aghion et al. (2019) argue that innovation raises top income inequality and, through the contribution of new inventors, enhances social mobility. A complementary perspective suggests that innovation, especially by new entrants, reduces inequality at the upper end of the income distribution by fostering turnover among entrepreneurs (Jones and Kim, 2018).[1]

Another strand of the literature investigates how the relationship between innovation and inequality is affected by patent policy (Chu and Peng, 2011; Chu and Cozzi, 2018; Chu et al., 2021), and monetary policy (Chu et al., 2019), and explores the role of innovation in shaping income inequality during the transition from pre-industrial stagnation to modern economic growth (Chu and Peretto, 2023). Peretto and Seater (2013) propose an R&D-driven growth theory of factor-eliminating technical change in which innovation increases the capital share of national income. Grossman and Helpman (2018) examine how firm and worker heterogeneity shape the impact of innovation on wage inequality. Sampson (2023) explore how international differences in R&D efficiency contribute to the formation of technology gaps and disparities in income levels among different countries.

The rest of the paper is structured as follows. Section 2 lays out the growth set-up. In Section 3, we solve the model and investigate how innovation shapes the distribution of income. Section 4 presents the econometric model and describes the dataset. Section 5 summarizes the dynamic properties of the variables and the causality analysis and then presents the results of an extensive long-run (cointegration) regression. Section 6 investigates the short-run response of inequality to innovation shocks through the event analysis. Section 7 assesses the transmission channels of innovation on income inequality. Finally, Section 8 concludes.

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[1] Less directly, our research is related to the literature that examines factors responsible for the path of inequality since the early 1980s, including skill-biased technical change (Acemoglu, 2002), automation (Acemoglu and Restrepo, 2020; Prettner and Strulik, 2020), education (Prettner and Schaefer, 2021), declining unionization (Farber et al., 2021), offshoring of labor-intensive production (Elsby et al., 2013), dominance of superstar firms and rising markups (Autor et al., 2020; Boar and Midrigan, 2019). Our paper specifically focuses on the inner source of the long-run trend in income inequality, viz technological development, which constitutes a major explanatory factor for recent trends in inequality.

2. Model

To illustrate the impact of innovation on income inequality, we consider a two-country version of the Schumpeterian quality-ladder model developed by Chu and Cozzi (2018) featuring households with different levels of asset holdings. We depart from this model by incorporating endogenous labor supply and cross-country spillovers arising from trade.[2] In our setup, both countries engage in innovation, but they may have different R&D productivities. The domestic country is denoted by the superscript d, and the foreign country is denoted by the superscript f. For the sake of conciseness, we will focus on the domestic economy, noting that for every variable and equation related to the home country, there are corresponding expressions for the foreign country. In what follows, we will outline the main features of the growth setup. For a more comprehensive explanation of the model and the derivation of key equations, refer to Appendix A.1.

2.1. Households

In country d, there is a unit continuum of households indexed by $x \in [0,1]$ with identical preferences for consumption and leisure and different levels of asset holdings. The lifetime utility function of household x is given by:

$$U^d(x) = \int_0^\infty e^{-\rho t}\left[\ln c_t^d(x) + \theta \ln(1 - l_t^d(x))\right] \mathrm{d}t,$$

where $\rho > 0$ is the discount rate and $c_t^d(x)$ is household x's consumption of the final good (the numeraire). Each household is endowed with one unit of time, which is allocated between work $(l_t^d(x))$ and leisure $(1 - l_t^d(x))$. $\theta > 0$ is the elasticity of instantaneous utility with respect to leisure. Each household earns both asset and labor income and maximizes utility, subject to the following constraint:

$$\dot{a}_t^d(x) = r_t^d a_t^d(x) + w_t^d l_t^d(x) - c_t^d(x), \tag{1}$$

where $a_t^d(x)$ is the value of financial assets owned by household x, r_t^d is the interest rate, and w_t^d is the wage rate (all expressed in real terms). At time 0, each household x has a share of total assets, $\phi_{a0}^d(x) \equiv a_0^d(x)/a_0^d$, which is exogenously given. We consider a general distribution function of the initial wealth share with a mean of one and a standard deviation of σ_a^d.

The Euler equation associated with this intertemporal optimization is:

$$\frac{\dot{c}_t^d(x)}{c_t^d(x)} = \frac{\dot{C}_t^d}{C_t^d} = r_t^d - \rho, \tag{2}$$

which shows that the growth rate of consumption is the same across households (upper case letters denote aggregate variables).

2.2. Final good

In country d, final output, Y_t^d, is a Cobb-Douglas aggregator of two types of gross outputs produced with domestic and foreign intermediate goods, Y_t^{dd} and Y_t^{df}, respectively:

$$Y_t^d = \frac{(Y_t^{dd})^\beta (Y_t^{df})^{1-\beta}}{\beta^\beta (1-\beta)^{1-\beta}}, \tag{3}$$

where $\beta \in (0,1]$ determines the importance of domestic goods in home final-good production. Final output can be used for consumption and R&D investment. Gross outputs in country d are produced using a Cobb-Douglas aggregator over a unit continuum of intermediate goods produced domestically, $X_t^{dd}(i)$, and imported from the foreign country, $X_t^{df}(j)$ (with $i, j \in [0,1]$), namely:

$$Y_t^{dd} = \exp\left(\int_0^1 \ln X_t^{dd}(i)\mathrm{d}i\right), \quad Y_t^{df} = \exp\left(\int_0^1 \ln X_t^{df}(j)\mathrm{d}j\right).$$

Profit maximization yields the conditional demand functions for intermediate goods $X_t^{dd}(i)$ and $X_t^{df}(j)$:

$$X_t^{dd}(i) = \frac{P_{yt}^{dd}}{p_{xt}^{dd}(i)} Y_t^{dd}, \qquad X_t^{df}(j) = \frac{P_{yt}^{df}}{p_{xt}^{df}(j)} Y_t^{df}, \tag{4}$$

where $p_{xt}^{dd}(i)$ and $p_{xt}^{df}(j)$ are, respectively, the price of $X_t^{dd}(i)$ and $X_t^{df}(j)$, whereas P_{yt}^{dd} and P_{yt}^{df} are the standard price indices for Y_t^{dd} and Y_t^{df}.

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[2] Employing a two-country model as a theoretical framework enables us to conduct a more realistic empirical analysis, which allows us to explore the impacts of foreign innovation and research productivity spillovers on inequality. Trade facilitates the transfer of technology and innovation across borders, resulting in productivity gains that have the potential to shape the dynamics of inequality.

2.3. Intermediate goods

Intermediate goods are freely traded, whilst labor is immobile across the two countries. In each industry $i \in [0,1]$, a monopolistic leader hires labor to produce intermediate goods and sells them to domestic and foreign firms, $X_t^{dd}(i)$ and $X_t^{fd}(i)$:

$$X_t^{dd}(i) = (z^d)^{N_t^d(i)} L_{xt}^{dd}(i), \qquad X_t^{fd}(i) = (z^d)^{N_t^d(i)} L_{xt}^{fd}(i), \tag{5}$$

where $z^d > 1$ is the step size of each productivity improvement, $N_t^d(i)$ is the number of productivity improvements that have occurred in industry i as of time t, while $L_{xt}^{dd}(i)$ and $L_{xt}^{fd}(i)$ denote, respectively, the amount of labor employed in the production of intermediate goods $X_t^{dd}(i)$ and $X_t^{fd}(i)$. As indicated by Eq. (5), innovation is cost-reducing.

The industry leader dominates the market temporarily until the arrival of the next innovation. Given the extant level of technology $(z^d)^{N_t^d(i)}$, the leader's marginal cost of producing one unit of the intermediate good is $w_t^d/(z^d)^{N_t^d(i)}$. The current and former industry leaders engage in a standard Bertrand competition, where the profit-maximizing price is a constant markup, $\psi \in (1, z^d]$, over the marginal cost, namely:

$$p_{xt}^{dd}(i) = p_{xt}^{fd}(i) = \psi \frac{w_t^d}{(z^d)^{N_t^d(i)}}.$$

2.4. R&D activity and innovation

Following the standard approach in the literature, we focus on the symmetric equilibrium (for a comprehensive analysis of symmetric equilibrium in quality-ladder growth models, see Cozzi et al., 2007). Therefore, in the subsequent discussion, we omit the index i. In each country, there is a unit continuum of R&D entrepreneurs, $\imath \in [0,1]$, that devote $R_t^d(\imath)$ units of the final good to R&D activities so as to maximize the expected profits, $\Pi_t^d(\imath) = v_t^d \lambda_t^d(\imath) - R_t^d(\imath)$, where $\lambda_t^d(\imath)$ is the firm-level arrival rate of innovation, and v_t^d represents the value of an innovation. Aggregating over entrepreneurs yields the arrival rate of innovations in the home country:

$$\lambda_t^d = \int_0^1 \lambda_t^d(\imath)\mathrm{d}\imath = \int_0^1 \vartheta^d \frac{R_t^d(\imath)}{D_t^d \Omega_t^d}\mathrm{d}\imath = \vartheta^d \frac{R_t^d}{D_t^d \Omega_t^d}, \tag{6}$$

where $\vartheta^d > 0$ is an exogenous parameter of technological productivity characterizing the R&D process of the domestic economy.

R&D productivity is often considered a measure of R&D efficiency due to different economic and socio-institutional factors not explicitly included in our growth framework. These factors include: (i) knowledge spillovers, absorptive capacity, and technology spillovers from the frontier; (ii) intellectual property rights, R&D infrastructure, and education policy; and (iii) lobbying and corruption, among others. In the empirical analysis below, we will account for most of these confounding factors to isolate the impact of the technological component of R&D productivity on income inequality.

In Eq. (6), the term $D_t^d \equiv (Z_t^d)^{\beta}(Z_t^f)^{1-\beta}$ denotes the aggregate index of R&D difficulty, which is a combination of the levels of technology in the two economies. This term captures the increasing complexity of technology (Segerstrom, 1998; Venturini, 2012). Consequently, one unit of R&D outlay is proportionally less effective in creating new technology as products become more sophisticated. Finally, $\Omega_t^d \equiv (L_t^d)^{\beta}(L_t^f)^{1-\beta}$ represents a growth trend that depends on the size of the workforce in each country. Scaling the arrival rate of innovation with Ω_t^d eliminates the scale effect on long-run growth.

3. Solving the model

We solve the model with a specific focus on the equilibrium characteristics and their implications for income distribution. For a more comprehensive analysis, refer to Appendix A.2 for insights into the dynamics of the overall economy, and to Appendix A.3 for further information on the effects of R&D productivity on the distribution of wealth and income.

3.1. Aggregate economy

Economic growth in the home country depends on the rates of technological progress in the two economies, which ultimately reflects their aggregate rates of innovation.[3] Defining aggregate technology in the home country as:

$$Z_t^d \equiv \exp\left(\int_0^1 N_t^d(i)\mathrm{d}i \ln z^d\right) = \exp\left(\int_0^t \lambda_s^d \mathrm{d}s \ln z^d\right),$$

the growth rate of Z_t^d becomes:

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[3] The aggregate effects exceed the domestic effects because the benefits of higher economic growth are shared with other countries through cross-country spillovers from trade in intermediate goods (Coe and Helpman, 1995; Coe et al., 2009).

$$\frac{\dot{Z}_t^d}{Z_t^d} = \lambda_t^d \ln z^d = \vartheta^d \frac{R_t^d}{\Omega_t^d D_t^d} \ln z^d .$$

The model features a unique and saddle-point stable balanced-growth path (BGP) along which the arrival rate of innovations and the interest rate remain constant, while all other aggregate variables grow at a constant and identical rate. In equilibrium, the arrival rates of innovation are stationary, $\lambda^d = \frac{\vartheta^d(\psi-1)}{\psi} - \rho$ and $\lambda^f = \frac{\vartheta^f(\psi-1)}{\psi} - \rho$, implying that the growth rates of technology, $\frac{\dot{Z}_t^d}{Z_t^d}$ and $\frac{\dot{Z}_t^f}{Z_t^f}$, are constant. The domestic variables $\{a_t^d, v_t^d, Y_t^d, \pi_t^d, C_t^d, w_t^d, D_t^d\}$ grow at the same rate, g^d, given by:

$$g^d = \beta\lambda^d \ln z^d + (1-\beta)\lambda^f \ln z^f = \beta \left[\vartheta^d \frac{(\psi-1)}{\psi} - \rho\right] \ln z^d + (1-\beta) \left[\vartheta^f \frac{(\psi-1)}{\psi} - \rho\right] \ln z^f , \tag{7}$$

which represents the steady-state growth rate in the domestic economy. Finally, the equilibrium expression for the domestic interest rate is given by $r_t^d = r^d = g^d + \rho$.

3.2. Income inequality

The income earned by each household consists of asset income and labor income. In this model, wealthier households enjoy greater asset income due to their larger asset holdings. Conversely, they receive lower labor income because they supply less labor.[4]

When analyzing income inequality, it is possible to show that the distribution function of income share at time t has a mean of one and a standard deviation (coefficient of variation) of:

$$\sigma_{It}^d = \frac{[r^d(1+\theta) - \rho\theta] a_t^d / w_t^d}{[r^d(1+\theta) - \rho\theta] a_t^d / w_t^d + 1} \sigma_a^d , \tag{8}$$

which we take as a measure of income inequality (for a derivation of the Gini coefficient of income and the top income shares, see Appendix A.3). As can be easily ascertained, the degree of income inequality, σ_{It}^d, is increasing in the interest rate, r^d, and the asset-wage ratio, a_t^d / w_t^d.

Changes in domestic R&D productivity, ϑ^d, can have positive or negative net effects on inequality depending on two opposing forces. The positive effect operates through the link between innovation and economic growth: an increase in ϑ^d promotes innovation within the domestic economy, leading to a higher arrival rate of innovations, λ^d. This accelerates economic growth (see Eq. (7)). The resulting increase in the growth rate, g^d, translates into a higher rate of return on assets, $r^d = g^d + \rho$, which tends to benefit wealthier households, thereby increasing income inequality (interest-rate effect). This occurs because the higher growth rate tends to favor households with substantial assets. Both components of their income—asset income and labor income—increase relative to those of poorer households. The increase in the second component of income is due to the fact that the labor supply of asset-wealthy households is more responsive to an increase in the growth rate when their labor supply is elastic. The interest-rate effect can be summarized as:

Lemma 1 *(Interest-rate effect). An increase in domestic R&D productivity exerts a positive effect on income inequality at home through the interest-rate channel:*

$$\frac{\partial \sigma_{It}^d}{\partial r_t^d} \frac{\partial r_t^d}{\partial \vartheta^d} > 0.$$

The inequality-reducing effect of increased R&D productivity operates through the asset-wage ratio, a_t^d / w_t^d and is related to the erosion of innovation rents due to creative destruction. Higher R&D productivity at home, ϑ^d, speeds up the arrival rate of innovation and reduces the market value of the existing firms (wealth dilution). As illustrated in Appendix A.3, this ratio can be expressed as:

$$\frac{a_t^d}{w_t^d} = \frac{a_t^d / Y_t^d}{w_t^d / Y_t^d} = \frac{1/\vartheta^d}{\theta\rho/\vartheta^d + (\theta+1)/\psi} = \frac{1}{\theta\rho + (\theta+1)\vartheta^d/\psi} .$$

This equation reveals that both the value of assets relative to income, a_t^d / Y_t^d, and the wage-income ratio, w_t^d / Y_t^d, decrease as ϑ^d increases. However, the increase in ϑ^d results in a larger decrease in financial wealth, a^d, compared to the decrease in the wage rate, w^d. Consequently, the asset-wage ratio diminishes with ϑ^d, contributing to a reduction in income inequality (asset-value effect). Therefore, the increasing creative destruction tends to mitigate income inequality by decreasing asset income relative to labor income. The asset-value effect can be summarized as:

Lemma 2 *(Asset-value effect). An increase in domestic R&D productivity exerts a negative effect on income inequality at home through the asset-value channel:*

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[4] In a model with inelastic labor supply, an individual's labor income is not influenced by their share of wealth in the economy. In the case of elastic labor supply, such as in our scenario, a negative relationship between wealth and labor income emerges. Indeed, as discussed in greater detail in Appendix A.3, wealthier households earn lower labor income due to their reduced labor supply.

$$\frac{\partial\, \sigma_{It}^{d}}{\partial\, (a_t^d/w_t^d)}\,\frac{\partial\, (a_t^d/w_t^d)}{\partial\, \vartheta^d} < 0.$$

Considering these opposing effects, the impact of a change in domestic R&D efficiency on income inequality in the home country is ambiguous. To shed light on the direction of this relationship, we conduct a calibration of this two-country model using aggregate data from 1985 to 2019 in Appendix A.4. Through a numerical exercise, we evaluate which of the two effects dominates. Specifically, we model a world consisting of the US and a foreign country, representing the weighted combination of six other innovation-intensive countries. Our quantitative analysis suggests that an increase in domestic R&D productivity is likely to result in higher income inequality.

Finally, it is important to note that an increase in foreign R&D productivity, ϑ^f, unambiguously influences domestic income inequality positively via the interest-rate channel. This is because the interest rate $r^d = g^d + \rho$ is affected by both domestic and foreign R&D productivity, as it is determined by a weighted average of domestic and foreign growth in technology. The asset-wage ratio, on the other hand, is only influenced by domestic R&D productivity. Indeed, an increase in foreign R&D productivity enhances economic growth in the home country through cross-country spillovers (see Eq. (7)).[5] As a result, domestic income inequality, σ_{It}^d, increases.

4. Empirics: model specification and data

We now examine the theory's predictions that domestic research productivity either stimulates income inequality through the interest-rate channel or impedes it via the asset-value channel, whereas foreign research productivity affects inequality solely through the interest-rate channel. To explore the relationship between research productivity and income inequality, we conduct panel regression analyses using various approaches. First, we employ cointegration methods to estimate a long-run reduced-form equation, where income inequality is regressed on research productivity (Section 5). Second, we utilize local projection analysis following Jordà (2005) to evaluate the short-term responsiveness of income inequality to exogenous shocks in research productivity, focusing on a change in the institutional settings governing international patent competition, and we compare these effects with counterfactual shocks (Section 6). Finally, we assess the distinct contributions of asset returns (through the interest-rate channel) and creative destruction (via the asset-value channel) using a two-stage regression framework, which helps elucidate how domestic research productivity influences income inequality (Section 7). This analysis will shed light on the direction of causality between R&D productivity and income inequality.

4.1. Cointegration model specification

To identify the long-run effects of R&D productivity on income inequality, we estimate the following log-linear model:

$$\ln \sigma_{it} = \alpha_i + \alpha_d \ln \vartheta_{it}^d + \alpha_f \ln \vartheta_{it}^f + \xi \mathbf{X}_{it} + \lambda_i u_t + \varepsilon_{it}, \tag{9}$$

where σ_{it} is income inequality, ϑ_{it}^d is domestic research productivity, ϑ_{it}^f is foreign research productivity, $\mathbf{X}_{it}$ is a vector of control variables whilst α_i is country fixed effects. λ_i captures the effect at the country level of the shocks due to common unobservable factors, here proxied by common correlated effects (CCE; see Chudik et al., 2016). Finally, ε_{it} is a disturbance term. Newey-West standard errors that are robust to serial correlation and heteroskedasticity are reported in the tables throughout. The coefficient α_d can take any sign depending on the strength of the interest-rate effect (positive) vis-á-vis the asset-value effect (negative). According to the predictions of our model, the impact of foreign research productivity should be unambiguously positive ($\alpha_f > 0$).

Eq. (9) estimates the long-term relationship between income inequality and research productivity. To allow for short-term dynamics in the long-run model, we design the previous equation as an error-correction model (ECM) representation while restricting the parameters to be homogeneous (subscripts $c = d$ or f):

$$\Delta \ln \sigma_{it} = \beta_i + \sum_{l=1}^{4} \beta_{\sigma,l} \ln \sigma_{it-l} + \sum_{l=0}^{4} \beta_{c,l} \Delta \ln \vartheta_{it-l}^c - \psi [\ln \sigma_{it-1} - \alpha_c \ln \vartheta_{it-1}^c] + \ldots + \varepsilon_{it}, \tag{10}$$

where the ECM formulation includes the term (ψ), which ensures that the model adjusts to its long-run equilibrium, and the term within the square brackets that corresponds to the disequilibrium (short-run) error. The ECM specification also includes lags of the dependent and right-side variables to capture the effect of simultaneous feedbacks, dynamic adjustments, etc. The ECM model yields long-run estimates that are asymptotically robust to reverse causality, measurement errors, and omitted variables. The country-specific intercepts, β_i, reflect systematic differences across countries in the dynamics of income inequality that do not vary over time.

We include up to four lags of the CCE terms, constructed as cross-sectional unweighted means of the variables of our regression model: their coefficients are allowed to vary across countries, noting that the CCE terms are excluded for foreign R&D productivity

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[5] Intuitively, when a foreign country engages in more innovative activities due to increased research productivity, for example, it subsequently boosts its exports of intermediate goods to the domestic country. Consequently, the demand for intermediate goods produced in the domestic economy also rises, as the production of the final good, given by Eq. (3), requires inputs from both domestic and foreign sources. This, in turn, leads to an increase in the growth rate of the domestic economy.

because they form a linear combination with domestic research productivity of partner countries. In a world of increasingly interconnected economies, it is vital to purge the influence of common unobservable factors, such as international technology shocks, knowledge spillovers, and absorptive capacity (see, e.g., Eberhardt et al., 2013; De Visscher et al., 2020).

4.1.1. *Control variables*

Given the potential endogeneity resulting from omitted variables, we include two sets of confounders identified in the literature as major factors influencing inequality: i) market structure and technology; and ii) social and institutional factors. Under market structure variables, we consider: i) Tobin's q, which measures the ratio between market value and capital replacement costs, serving as an indicator of market rent or pure profit (Kerspien and Madsen, 2024); ii) the Herfindahl–Hirschman index of patent ownership,[6] and iii) the proportion of firms annually exiting the technology market relative to active companies by technology class. Extensive literature suggests that increasing market concentration and markups have contributed to inequality trends in recent decades (see, e.g., De Loecker et al., 2020; Barkai, 2020; Kerspien and Madsen, 2024). Additionally, we use the share of machinery in total fixed investment as a proxy for mechanization, given that the adoption of advanced and efficient machines can exacerbate inequality, as noted by Prettner and Strulik (2020) in the context of automation, for example.

The second set of controls encompasses social and institutional characteristics of countries, including tertiary educational attainment, income per capita, average taxation rate, and unionization rates. Tertiary education is included as it is the ultimate source of a country's ability to generate new ideas and influences income inequality through the skill premium. Income per capita reflects the income distributional effects of economic development, as indicated by the Kuznets Curve (Kuznets, 1955; Aghion et al., 2023). The share of tax revenues in total GDP is included due to its potential to crowd out investment and influence the wealth income of high earners (Roine et al., 2009; Piketty, 2014; Islam et al., 2018). Finally, union membership rates are included as a proxy for union strength (see, e.g., Madsen et al., 2018a).

4.2. *Data*

The model is estimated for 21 OECD countries over the period 1920-2019: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the UK, and the US.[7] The starting year of 1920 is determined by data availability. Additionally, formal research conducted by corporations was negligible before 1920, and the manufacturing sector—where the majority of R&D activities are concentrated—began to gain prominence during the interwar period in most countries in our sample (Madsen et al., 2021).

We use a set of indicators that measure different dimensions of income inequality: the top 5% income share, the Gini coefficient, and the ratio of capital to labor income, referred to as the factor income ratio. We exclude labor income of the self-employed from the operating surplus (considered as capital income) and include it in labor income, assuming that the self-employed are paid the average wage rate. The Gini coefficient and the top 5% income share are based on pre-tax income, excluding transfers (referred to as market Gini), because net income inequality data has only recently become available.

Following the well-established literature on returns to research (Stafford, 1952; Kortum, 1993; Bloom et al., 2020), we construct two measures of R&D productivity: the number of patents applied for in domestic and foreign markets by residents of country i divided by i) domestic real R&D expenditure; ii) the number of R&D workers; and iii) real investment in intellectual property products (IPP). Data on patents applied for by residents in the home market, i.e., country i, are readily available from the World Intellectual Property Office (WIPO). However, patents applied for by residents of country i in country j are not directly available but are collected from official statistics of country j before 1972 when the WIPO data were unavailable. Foreign R&D productivity (ϑ^f) is primarily measured as the bilateral import-weighted average of trade partners' research productivity in our sample of 21 countries: $\vartheta^f_{it} = \sum_{j=1}^{21} m_{ijt} \cdot \vartheta^d_{jt}$, where $i \neq j$ and $m_{ijt} = M_{ijt}/Y_{it}$ is the share of country i's imports from country j expressed in a common currency. As alternative weights, we use the inverse geographical distance, which has the advantage of not being affected by changes in income inequality and, therefore, is immune to feedback effects from the dependent variable. Finally, we use cultural proximity, which places stronger weight on inequality exerted by innovation conducted by countries with similar values and beliefs concerning property rights, profits, wealth, etc., proxied here by the degree of individualism (see Madsen and Farhadi, 2018). In the robustness checks, we consider quality-adjusted measures of innovation output by weighting the number of patent counts by a quality index that reflects the number of citations received (forward citations) and the degree of originality of patented innovations (Hall et al., 2001).

Real R&D expenditure is available from the OECD starting from around 1970, depending on the country in question. The data is retropolated using a combination of historical reconstructions of nominal R&D expenditure, government expenditure on R&D and tertiary education, and statistical periodicals. The nominal R&D expenditure is deflated by a weighted average of wages of researchers and the acquisition cost of buildings and machinery. The data is constructed by Madsen et al. (2021). The real IPP data has only been collected relatively recently by the OECD and national statistical agencies because it recently transitioned from being expensed to being capitalized in the System of National Accounts. For that reason, it first becomes available sometime after 1960, depending on

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[6] This variable is computed at the level of the four-digit IPC class to account for the effect of an innovation-led change in market concentration. It exploits the information of disambiguated applicants' names as provided by the Comprehensive Universe of U.S. Patents dataset (CUSP) (see, e.g., Berkes, 2018). The CUSP dataset provides information on patent applications filed at the USPTO over the period 1836-2016.

[7] See the online Appendix, Section D for data sources.

the country in question. We retropolate the IPP data using R&D expenditure and deflate it by a weighted average of wages of R&D workers, prices of machinery and equipment, and housing rent.

The number of R&D workers is available from the OECD starting from around 1980, depending on the country in question. Before then, only a few observations on STEM researchers (science, technology, engineering, and mathematics) are available from national sources. Almost all of the pre-1980 data are measured as the stock of individuals of working age with a STEM degree and spliced with the number of researchers at the first year at which official data is available. The working age population with a STEM degree is constructed from data on students enrolled in STEM courses in the years at which the education was taken for each age cohort and the contemporaneous population decomposed by ages, meaning that we need data for enrollment in STEM courses back to 1872 to construct the stock of R&D personnel starting from 1920. In 1920, the number of persons aged 64 with a STEM degree, for example, is estimated as the average number of students enrolled in STEM courses over the period from 1872 to 1876. The method used to estimate the educational attainment from enrollment data and age-dependent population data is derived by Madsen (2014). Enrollments in STEM degrees are taken from various statistical sources and often supplemented with enrollment data from university calendars for each individual university in a country.

4.3. *Graphical analysis*

Fig. 1 shows a long-term downward trend in domestic R&D productivity, measured as the number of patents per dollar spent on R&D, and the top 5% income share for the 21 countries considered here since 1870. The downward productivity trend is particularly pronounced between 1920 and 2019, the period covered by our empirical analysis. The top 5% income share declines over the period 1920-1982. Despite the decrease in research productivity throughout the entire period, it has increased since 1982, predominantly because other drivers of inequality, such as biased technological change (Karabarbounis and Neiman, 2014; O'Mahony et al., 2021), decreasing labor power (Blanchard, 1997), increasing markups (Autor et al., 2020; Kerspien and Madsen, 2024), and globalization (Elsby et al., 2013) have pulled in the opposite direction.

Fig. 2 shows a robust positive relationship between the growth in domestic R&D productivity and the top 5% income share, where the observations are average annualized growth rates over the periods 1920-1945, 1945-1970, 1970-1995, and 1995-2019. Long-term intervals are used to smooth out random and cyclical fluctuations so that the data points capture the long-run variation between the variables. This relationship is highly statistically significant, as indicated by the statistical significance of the slope coefficient of the fitted line at the 95% confidence level.

5. Regression results

We first undertake cointegration regressions in which we examine i) the relationship between income inequality and research productivity while controlling for important confounders; ii) the sensitivity of the results to the measurement of research productivity, its decomposition into patents and R&D; and, iii) the time frequency of this data and other econometric issues.[8]

5.1. *Baseline results*

The baseline cointegration regression results with the top 5% income share, the Gini coefficient, and the factor income ratio as outcome variables are presented in Table 1. The coefficients of domestic research productivity are all highly significantly positive regardless of the measure used for income inequality. The largest elasticity of research productivity is found for the factor income ratio (0.095), followed by the Gini coefficient (0.044), and the top 5% income share (0.030) as outcome variables. The relatively high coefficient of the factor income ratio reflects its high standard deviation relative to that of the other inequality measures, especially due to the large fluctuations in the interwar period.

The coefficients of foreign research productivity are significantly positive in most cases (seven out of nine regressions). This suggests that the dominant effect of this force is positive, as predicted by the model, thus amplifying the domestic R&D productivity effects on income inequality.

5.2. *Inclusion of confounders in the cointegration model*

We check for endogeneity due to the omission of confounders in Table 2. For the sake of brevity, we include all the market structure variables in one set of regressions and the social and institutional variables in another set. The regressions in columns (1), (4) and (7) are the baseline regressions from Table 1. First, consider the inequality effects of the changing market structure and mechanization in columns (2), (5), and (8) of Table 2. The coefficients of Tobin's q are negative and significant in two of the three cases when we control for all technological factors, including the degree of concentration, the exit rate from the technology market, and the mechanization rate. As expected, the impact of technological concentration is largely positive and significant, indicating that increasing market power of innovative companies leads to an increase in income inequality. Conversely, income inequality is

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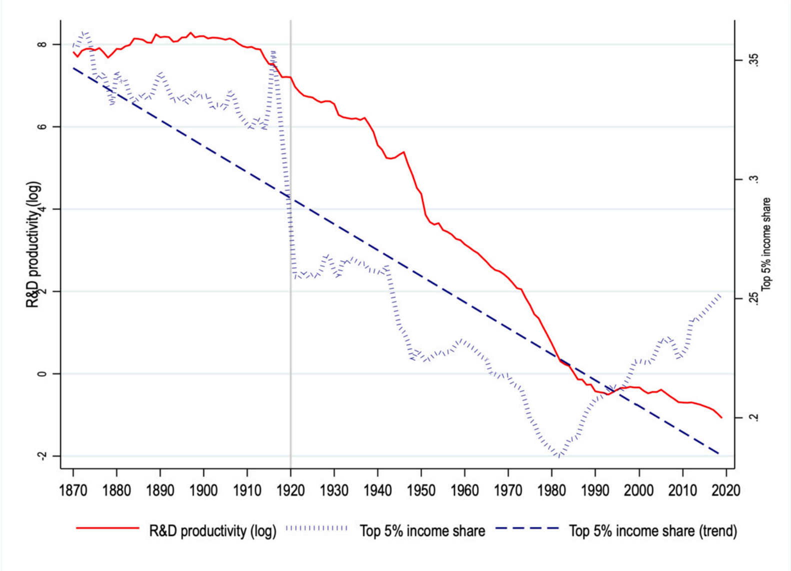
[8] For a detailed assessment of the statistical properties of the variables and their interrelationships, see the online Appendix, Section C.1, which shows: i) that research productivity and all measures of inequality contain unit roots (Table C1) and ii) there exists a stationary, long-run cointegration relationship between the variables (Table C2).

Table 1

Baseline estimates (Long-run estimates, 1920-2019).

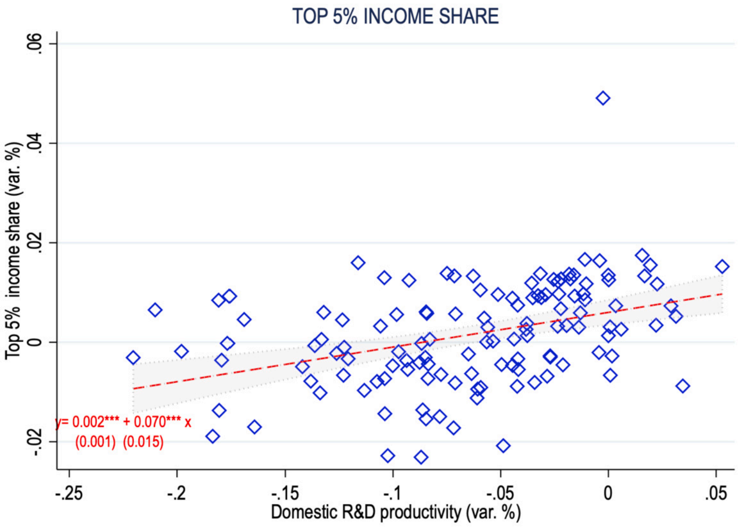
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Top 5% income share				Gini				Factor income ratio			
Domestic R&D productivity	0.030***	0.027***	0.029***	0.045***	0.044***	0.031***	0.039***	0.065***	0.095***	0.113***	0.115***	0.047***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.011)	(0.008)	(0.008)	(0.013)
Foreign R&D prod. (Bilateral imports)	0.013***			0.012***	0.021***			0.070***	−0.032***			−0.123***
	(0.004)			(0.004)	(0.004)			(0.003)	(0.012)			(0.015)
Foreign R&D prod. (Geographical proxi.)		0.113***				−0.091***				0.101**		
		(0.020)				(0.017)				(0.044)		
Foreign R&D prod. (Cultural proximity)			0.168***				0.164***				0.179***	
			(0.012)				(0.011)				(0.026)	
Trade openness				0.005				−0.165***				−0.051*
				(0.010)				(0.007)				(0.026)
ECM term	−0.137***	−0.137***	−0.141***	−0.173***	−0.104***	−0.105***	−0.107***	−0.123***	−0.222***	−0.220***	−0.222***	−0.289***
	(0.019)	(0.019)	(0.018)	(0.021)	(0.012)	(0.012)	(0.012)	(0.012)	(0.030)	(0.029)	(0.029)	(0.037)
Observations	1,911	1,911	1,911	1,911	1,911	1,911	1,911	1,911	1,874	1,874	1,874	1,874
R-squared	0.906	0.912	0.910	0.751	0.928	0.932	0.930	0.825	0.859	0.858	0.858	0.654

Notes: The estimates are obtained from the pooled error-correction model that includes country fixed effects and common correlated effects. All variables are measured in logs. The ECM term is the coefficient of the one-year lagged level of the dependent variable and measures the speed of adjustment towards the equilibrium relationship. The number of time lags for the first-difference regressors and common correlated effects is set to 4. Newey-West standard errors are in parentheses. R&D productivity is measured as the ratio between patent counts and real R&D expenditure. ***, ** and * significant at 1, 5 and 10%, respectively.



Notes: Domestic R&D productivity is measured as the logs of the ratio between the counts of patent applications by residents and real R&D expenditure. All measurements are based on unweighted averages of the 21 countries considered here.

Fig. 1. Long-run trend in domestic R&D productivity and top 5% income share.



Notes: Average annual rates of change in domestic R&D productivity (domestic patents divided by real R&D expenditure) and in the top 5% income share over the periods 1920-1945, 1945-1970, 1970-1995, and 1995-2019. The dashed line represents the linear regression slope between the two variables.

Fig. 2. Correlation between growth rates in income inequality and domestic R&D productivity.

negatively affected by mechanization as this process is likely to increase the skill premium, provided that high-skilled workers and new machines are complementary in production.

Next, consider the social and institutional confounders (columns (3), (6), and (9) of Table 2). The coefficients of the share of the working-age population with tertiary education are significantly negative in the estimates with the top income share and the Gini index as outcome variables, but positive at the 10% level in the regression using the factor income ratio as the dependent variable. The weakly significant positive effect of tertiary education on the factor-income ratio suggests that higher education is more complementary to capital than to raw labor, implying that an increase in education enhances the marginal productivity of productive assets. While this effect also applies to the Gini coefficient and the top 5% income share, these outcome variables are additionally influenced by between-labor inequality through the following two channels. First, an increasing supply of the working-age population with tertiary education reduces the skill premium, assuming that the elasticity of substitution between skilled and unskilled labor is greater than one. This effect is tempered if skill-biased technical progress induced by skilled labor is not strong enough to counteract

Table 2
Estimates with controls (Long-run estimates, 1920-2019).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Top 5% income share			Gini			Factor income ratio		
Domestic R&D productivity	0.030***	0.046***	0.046***	0.044***	0.054***	0.107***	0.095***	0.056***	0.079***
	(0.003)	(0.004)	(0.005)	(0.003)	(0.003)	(0.004)	(0.011)	(0.013)	(0.012)
Foreign R&D productivity	0.013***	0.028***	0.028***	0.021***	−0.032***	0.018***	−0.032***	0.017	−0.117***
(bilateral imports)	(0.004)	(0.004)	(0.006)	(0.004)	(0.004)	(0.004)	(0.012)	(0.013)	(0.012)
Market Structure & Technology									
Tobin's *q*		−0.018***			−0.004			−0.069***	
		(0.007)			(0.004)			(0.017)	
Tech concentration		0.007***			0.014***			0.006***	
		(0.001)			(0.001)			(0.002)	
Market exit rate		0.138***			−0.032***			−0.094***	
		(0.009)			(0.007)			(0.024)	
Mechanization rate		−0.149***			−0.047***			−0.104***	
		(0.007)			(0.006)			(0.018)	
Social & Institutional Factors									
Tertiary education			−0.582***			−0.924***			0.318*
			(0.082)			(0.067)			(0.168)
Income per capita			−0.081***			−0.128***			−0.568***
			(0.019)			(0.016)			(0.060)
Unionization rate			−0.004			0.080***			−0.094***
			(0.007)			(0.006)			(0.016)
Tax revenues/GDP			−0.052***			0.076***			−0.040***
			(0.006)			(0.005)			(0.014)
Observations	1,911	1,889	1,911	1,911	1,889	1,911	1,874	1,852	1,874
R-squared	0.906	0.851	0.797	0.928	0.870	0.855	0.859	0.791	0.708

Notes: The estimates are obtained from the pooled error-correction model that includes country fixed effects and common correlated effects. The ECM term is the coefficient of the one-year lagged level of the dependent variable and measures the speed of adjustment towards the equilibrium relationship. The number of time lags for first-difference regressors and common correlated effects is set to 4. Newey-West standard errors are in parentheses. All variables are measured in logs. ***, ** and * significant at 1, 5 and 10%, respectively.

the relative supply effect (see, for a theoretical analysis, Acemoglu, 1998 and Kiley, 1999). Second, for a constant skill premium, an increase in the skilled labor force relative to workers with lower levels of education initially increases between-labor inequality but eventually decreases, following a pattern similar to the Kuznets curve. The negative coefficients of tertiary education in the regressions with the top income share and the Gini index as outcome variables suggest that educational expansion has reduced between-labor inequality.

The coefficients of per capita income are all significantly negative, which is consistent with the Kuznets Curve, provided that most countries in our sample are on the declining side of the inverse U-shaped curve. The coefficient of unionization is significantly negative in the regression with the factor-income ratio as the outcome variable, as it enhances the negotiation strength of labor. Conversely, and counter-intuitively, unionization is positively related to the Gini coefficient, which may be a result of a spurious correlation. Finally, the coefficients of tax in total GDP are significantly negative, except in the regression with the Gini index as the outcome variable. This suggests that middle-income earners benefit the most from higher taxation, while high-income earners, who get a large share of their income from capital, are the ones to lose the most from higher taxation.

Turning to the focus variables, the coefficients of domestic research productivity remain significantly positive in this set of regressions. The parameter for this explanatory variable is slightly higher when controls are included in the models for the top 5% income share and the Gini coefficient. This suggests that the baseline regressions might underestimate the true impact of research productivity due to the omission of important control variables that affect inequality. Conversely, when the factor income ratio is used as outcome variable, the coefficients of domestic research productivity are reduced when confounders are controlled for. The coefficients of foreign R&D productivity are consistently significantly positive in the regressions with top 5% income inequality as the outcome variable, but they are unstable and sensitive to the inclusion of confounders in the regressions where the outcome variables are the Gini coefficient and the factor income ratio.

5.3. *Alternative measures of research productivity*

The results presented thus far are based on three different measures of income inequality using a single measure of research productivity. To overcome this limitation, we assess the sensitivity of our findings by using two alternative measures of R&D inputs: R&D workers and IPP expenses (Table 3). The results based on the top 5% income share, the Gini coefficient, and the factor income ratio as outcome variables are shown, respectively, in the left, middle, and right-hand panels of the table. Foreign research productivity is based on bilateral import weights in all the estimates. Our key findings are largely confirmed using these new proxies for research productivity.

Next, we decompose the inequality impact of research productivity into that attributable to innovation output (patent counts) and that associated with innovation input (R&D expenditure). The former variable captures the effect of the rents (profits) generated by the development of new technologies, while the latter reflects the remuneration of the inputs used in these processes, with R&D personnel constituting the lion's share of this expenditure. Column (2) of Table 3 presents the results of this decomposition for our baseline measure of R&D productivity, considering patent counts and R&D expenses as explanatory variables. A similar exercise using R&D workers or IPP expenses in addition to patent counts as regressors is reported in Table C6 of the online Appendix, Section C.3. The results shown in columns (2), (6), and (10) of Table 3 are consistent with the model predictions: the coefficients of patents are all significantly positive, and those of R&D are significantly negative, except in the case where the top 5% income share is the dependent variable. As shown in Table C6, similar results are obtained when R&D is measured using both R&D workers and IPP expenses.

The estimated impact of patenting on inequality is consistent with the evidence provided by Aghion et al. (2019) for the US states and Bengtsson et al. (2020) in a cross-country study on the determinants of the income share of capital. Furthermore, the impact that R&D expenditure has on the factor income ratio is consistent with the effect of R&D on labor's share of national income found by O'Mahony et al. (2021). Increasing evidence shows that innovation rents are partly appropriated by workers of any occupation, even though these benefits are unevenly distributed, with employees at the very top tail of the income distribution, such as top executives, gaining the most (Van Reenen, 1996; Kline et al., 2019).

5.4. *Long-term interval regression and further robustness checks*

As a further check, we assess the sensitivity of the results to the use of annual data by running the regression model using 5-year non-overlapping intervals. This analysis examines whether the time frequency of the data and the short-run dynamic adjustment of the variables featuring several adverse events over a century (i.e., the Great Depression, WWII, the oil price shocks, and the Great Recession) affect the estimates of the inequality effects of R&D productivity. The estimates in Table 4 show that, on average, the magnitude and significance of the coefficients of research productivity are larger than those with annual data. Along with the effect of adverse events, the lower coefficients associated with estimates using annual data might also be due to the noise in our series for the earlier period of the time interval, which could produce the classical attenuation bias. As expected, the estimated speed of adjustment towards the long-run equilibrium is much faster in the 5-year interval estimates than in the baseline regressions. A caveat in the factor income ratio regression is that the speed of adjustment is smaller than -1. This implies that the adjustment towards the long-run equilibrium is not monotonic, indicating some instability in the long-run relationship between this indicator of inequality and our measures of research productivity.

Further sensitivity tests are reported in the online Appendix, Sections C.2 and C.3. First, reducing the number of lags of the variables from four to two slightly improves the results: the coefficient of domestic research productivity increases in magnitude and achieves higher levels of statistical significance, while all elasticities of foreign research productivity are positive (see Table C3 of the online Appendix, Section C.2). Second, the inequality effect of research productivity is assessed using alternative dynamic estimators that are robust to simultaneity feedback effects and to the order of integration of the variables (cross-sectionally augmented autoregressive distributed lag, CS-ARDL, model), or that have good small-sample performance (cross-sectionally augmented distributed lag, CS-DL, model; see Table C4 of the online Appendix, Section C.2). These robustness checks do not provide any evidence against the benchmark regressions. Finally, the coefficients of domestic research productivity remain close to those of the baseline regressions when the counts of patent applications are quality-adjusted, i.e., multiplied by the number of forward citations. In these regressions, foreign research productivity has a negative coefficient, likely reflecting the home bias associated with the data, which may lead to underestimating patent activities in some countries compared to the US (see Table C5 of the online Appendix, Section C.3).

6. Event study: inequality response to a shock in the patent propensity

In this section, we perform an event study to assess the sensitivity of income inequality to an exogenous shock to research productivity and compare the inequality response to our baseline long-run estimates. To this end, we consider the inequality effects of a change in the institutional setting governing international patent competition and treat the year in which the Patent Cooperation Treaty (PCT) came into force in a country as an event. The PCT, which is administered by the World Intellectual Property Organization, allows an applicant to extend the legal protection of an innovation from the home country to worldwide coverage in a preferential way, thus saving the costs of applying separately in each partner country. We use the change in the Intellectual Property Rights (IPRs) to identify the effect of a greater facility to exploit innovation rents on income inequality.[9]

To conduct the event study, we employ the local projection (LP) method (Jordà, 2005) and simulate the dynamic response of income inequality to the signing of the PCT. We compare this effect against the change in inequality associated with the peak year in research productivity and, as counter-factual exercises, against the impact on the income distribution induced by a random shock or by the entry of countries in our sample to the European Union.

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[9] Bhattacharya et al. (2022) assess how the imposition of stronger Intellectual Property Rights (The Patents Amendment Act, 2002) affected wage inequality in Indian manufacturing firms by shifting the law enforcement from process to product innovation, thereby favoring the compensation of top managers. Deepak et al. (2023) show that the American Inventor's Protection Act influenced both patent and R&D performance of US companies exposed to this institutional change by speeding up patent disclosure.

Table 3
Robustness estimates: measurement issues (1920-2019).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Top 5% income share				Gini				Factor income ratio			
Domestic R&D prod.	0.030***		0.096***	0.028***	0.044***		0.035***	0.043***	0.095***		0.078***	0.107***
	(0.003)		(0.002)	(0.002)	(0.003)		(0.002)	(0.002)	(0.011)		(0.007)	(0.008)
Foreign R&D prod.	0.013***	0.070***	0.014***	0.011***	0.021***	0.011**	−0.007***	0.008***	−0.032***	0.026**	−0.019**	−0.003
(bilateral imports)	(0.004)	(0.005)	(0.002)	(0.001)	(0.004)	(0.005)	(0.002)	(0.001)	(0.012)	(0.012)	(0.008)	(0.004)
Patent counts		−0.004				0.110***				0.205***		
		(0.005)				(0.004)				(0.014)		
R&D expenses		−0.081***				−0.048***				−0.153***		
		(0.005)				(0.004)				(0.016)		
ECM term	−0.137***	−0.230***	−0.101***	−0.140***	−0.104***	−0.123***	−0.083***	−0.105***	−0.222***	−0.263***	−0.167***	−0.229***
	(0.019)	(0.023)	(0.013)	(0.019)	(0.012)	(0.013)	(0.010)	(0.012)	(0.030)	(0.039)	(0.023)	(0.030)
R&D productivity	Patent counts / R&D expenses		Patent counts / R&D workers	Patent counts / IPP expenses	Patent counts / R&D expenses		Patent counts / R&D workers	Patent counts / IPP expenses	Patent counts / R&D expenses		Patent counts / R&D workers	Patent counts / IPP expenses
Obs	1,911	1,869	1,911	1,910	1,911	1,869	1,911	1,910	1,874	1,833	1,874	1,873
R-squared	0.906	0.833	0.911	0.909	0.928	0.886	0.935	0.932	0.859	0.804	0.895	0.856

Notes: Long-run estimates based on the pooled error-correction model. All variables are measured in logs. The estimates include country fixed effects and common correlated effects. The number of time lags for first-difference regressors and common correlated effects is set to 4. The ECM term is the coefficient of the one-year lagged level of the dependent variable and measures the speed of adjustment towards the equilibrium relationship. Newey-West-corrected standard errors are in parentheses. R&D productivity is measured as the ratio between patent counts and real R&D expenditure in column (1), as the ratio between patent counts and R&D workers in column (3), and as the ratio between patent counts and real IPP expenditure in column (4). ***, ** and * significant at 1, 5 and 10%, respectively.

Table 4

Estimates based on 5-year non-overlapping intervals (1920-2019).

	(1)	(2)	(3)
	5-year intervals		
	Top 5% income share	Gini	Factor income ratio
Domestic R&D productivity	0.090***	0.032**	0.135
	(0.028)	(0.012)	(0.096)
Foreign R&D productivity (bilateral imports)	0.120***	0.080***	0.117**
	(0.024)	(0.015)	(0.046)
ECM term	−0.802***	−0.609***	−1.141***
	(0.124)	(0.041)	(0.210)
Observations	315	315	315
R-squared	0.543	0.394	0.467

Notes: Long-run estimates based on the pooled error-correction model. All variables are measured in logs. The estimates include country fixed effects and common correlated effects. The number of time lags for first-difference regressors and common correlated effects is set to 1. The ECM term is the coefficient of the one-year lagged level of the dependent variable and measures the speed of adjustment towards the equilibrium relationship. Newey-West standard errors are in parentheses. R&D productivity is measured as the ratio between patent counts and real R&D expenditure. ***, ** and * significant at 1, 5 and 10%, respectively.

The standard approach of LP involves running a set of linear regressions of future realizations of income inequality on the current values of a set of covariates (including the event variable). Following Romer and Romer (2017) and Ciminelli et al. (2022), we consider an extended version of the baseline LP approach, estimating the following specification[10]:

$$\sigma_{i,t+k} = \alpha_i + \alpha_t + \sum_{h=0}^{k}(\alpha_1^h E_{it+h} + \alpha_2^h \mathbf{X}_{i,t+h}) + \sum_{l=1}^{3}(\alpha_3^l \sigma_{i,t-l} + \alpha_4^l E_{i,t-l} + \alpha_5^l \mathbf{X}_{i,t-l}) + \varepsilon_{it}, \tag{11}$$

where σ_i is the inequality indicator, k defines the time horizon ($k = 1, ..., 5$) over which we compute the response of the outcome variable to the event occurring at time $t = 0$. E is the event indicator which takes the unitary value in the year of adhesion to the PCT and 0 otherwise. $\mathbf{X}$ is a vector that contain the following controls: foreign R&D productivity, Tobin's q, the share of the population with tertiary education, per capita income, the share of tax revenues in GDP, union membership. α_i and α_t are country and year effects, while ε_{it} is a disturbance term. Our empirical model also accounts for forward effects of the event and control variables, as well as for feedback effects, including the lagged impact of regressors and the dependent variable (up to three-year lags). The model is estimated with the FE-OLS estimator using heteroskedasticity-robust standard errors. We consider data over the period 1970-2019 as the PCT started to come into effect in 1978 (which is also the modal year of the event), with the last country in our sample joining the treaty in 1992.

The top left-hand diagram in Fig. 3 shows the response function for the top 5% income share and the associated 90% and 95% confidence intervals to a shock in domestic research productivity. The reported values correspond to the percentage point change in income inequality. The top 5% income share increases by 0.85 percentage points over the 5-year horizon after the event and is significantly different from zero at the 5% level. This change corresponds to a logarithmic increase of 0.035 relative to the pre-treatment value of inequality of 23.6%, which aligns with the long-run elasticities reported in columns (1)-(4) of Table 1.[11]

To assess the robustness of these results, we simulate the evolution of the top 5% income share after a peak year in research productivity (top right-hand panel in Fig. 3). The event variable takes a unitary value in the year with the highest research productivity between 1970 and 2019 (see Jordà and Taylor, 2016). Five years after the event, top income inequality is about 1.5 percentage points larger than the pre-event period. This response corresponds to a 0.063 log-increase, which is a less conservative value than that found in the baseline regressions.

As a further robustness check, we simulate the response of income inequality to (i) the entry of most countries of our sample into the European Union; and (ii) to a randomly assigned event year. We estimate the first model over the period 1950-2019 as the signing of the Treaty of Rome dates from March 25th, 1957. In both cases, the responses of inequality are considerably different from those illustrated in the top part of Fig. 3 as the top 5% income share does not show any significant change after the event. Since neither of these events should have any impact on income inequality, these results suggest that the baseline findings in the two first event studies are not driven by spurious correlation.

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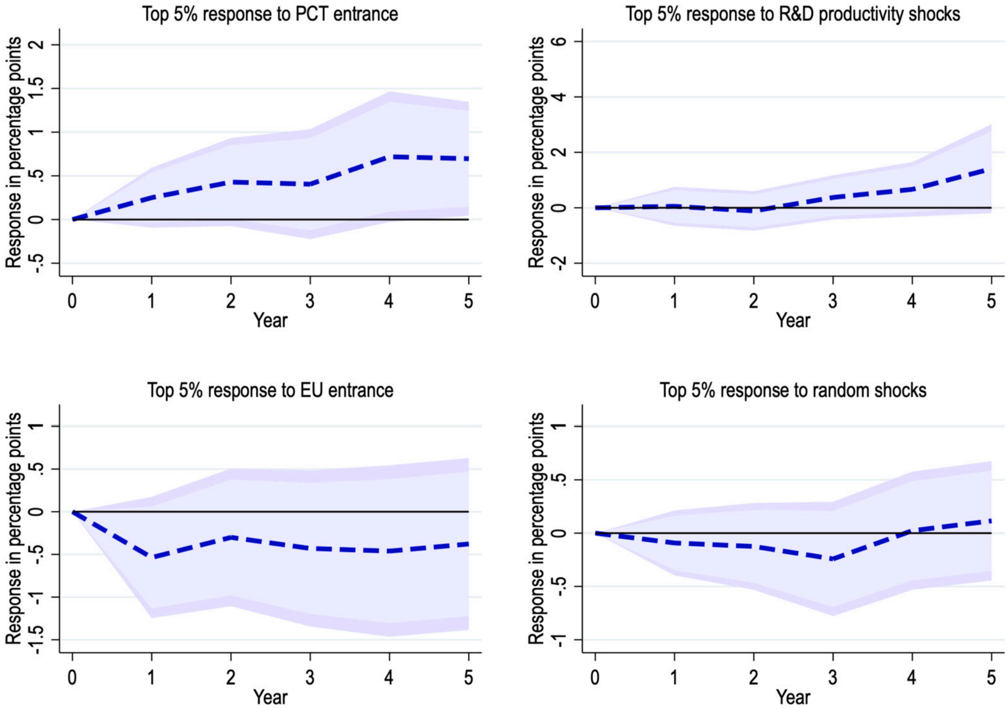
[10] The LP approach has garnered increasing recognition for its computational simplicity and the fewer assumptions needed for identification compared to other popular methods such as Vector Autoregression (VAR). In LP settings, identification is typically achieved using external variables, and this approach has recently been utilized in the treatment analysis of macroeconomic processes, as in Difference-in-Difference (DiD) analysis (see for instance Dube et al., 2023). Despite its many benefits, a limitation of the LP method is the imprecision of estimates, as the confidence intervals of LP-based responses can be wide. To address this issue, researchers have developed Bayesian methods of LP analysis (Ferreira et al., 2024) or optimal linear methods that efficiently combine impulse response estimators (Ho et al., 2024).

[11] The simulated increase in the top 5% income share is comparable to the inequality change associated with conventional monetary policy shocks, i.e., a 25 basis point reduction in the repo rate (Amberg et al., 2022) or an unanticipated increase of 100 basis points in the short-term interest rate (Furceri et al., 2018).



Notes: LP coefficient estimates (α_{1k}). Bands in dark and light blue signify 90% and 95% confidence intervals, respectively, based on Eicker-Huber-White heteroskedasticity-robust standard errors. The reported values correspond to the absolute percentage point change in inequality (Y-axis) over a 5-year horizon (X-axis). The model is regressed over the period 1970-2019, except in the bottom left-hand panel, where the model is estimated over the period 1950-2019. The following controls are included in the estimates: foreign R&D productivity, Tobin's q, the share of the population with tertiary education, per capita income, the share of tax revenues in GDP, union membership.

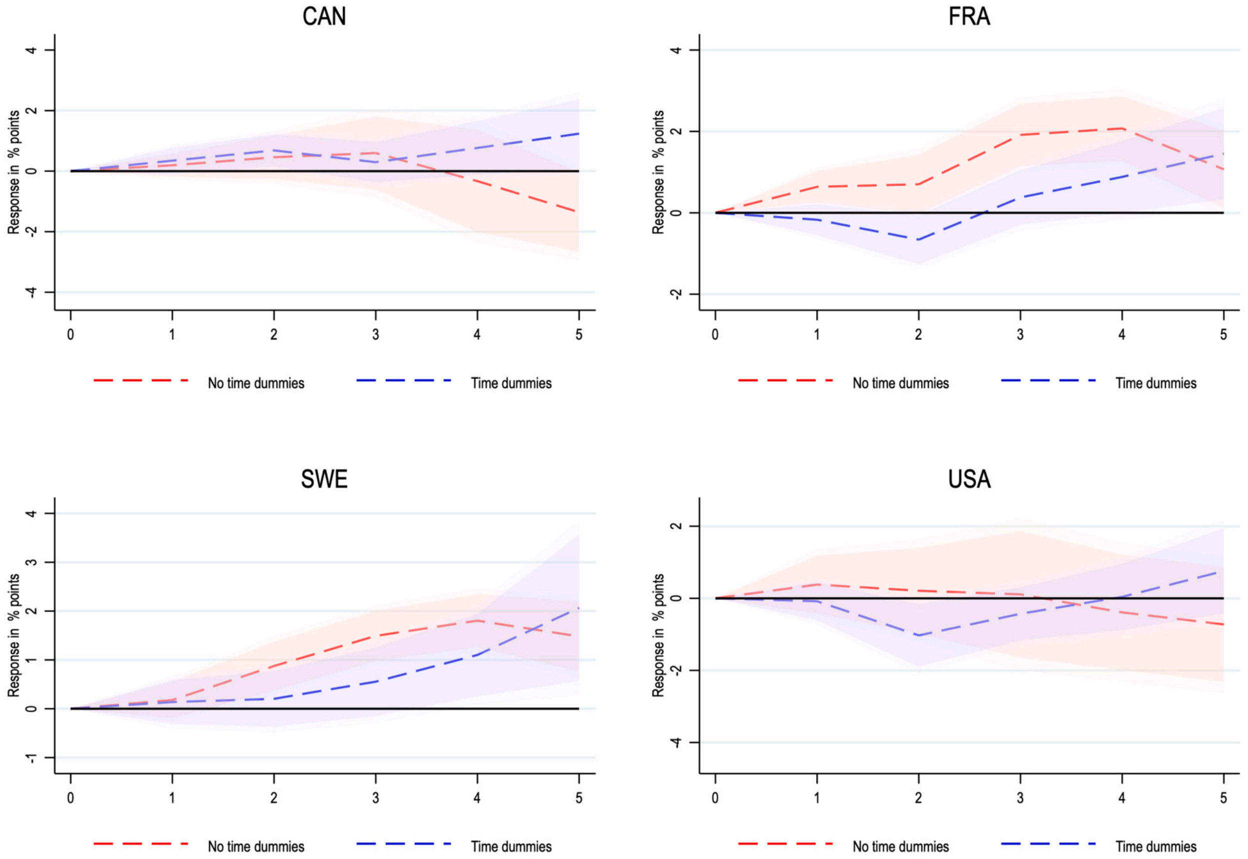
Fig. 3. Response of the top 5% income share to shocks to domestic R&D productivity. (For interpretation of the colors in the figure(s), the reader is referred to the web version of this article.)

We now turn to the inequality-effects of shocks to foreign research productivity. Figs. B.1 and B.2 in Appendix B.1 provide insights into both the response of the pool of countries and the specific responses of the individual economies. Specifically, we simulate the dynamic path in the top 5% income share in response to peak increases in bilateral import-weighted foreign R&D productivity. For the pool of countries, our LP (panel) specification includes country and time fixed effects, along with the same set of control variables used in Fig. 3. The response of income inequality is not statistically significant, which is likely due to the large heterogeneity across countries (see Fig. B.1). However, individual country LP regressions reveal a positive response of income inequality for a subset of economies, as illustrated in Fig. 4 for Canada, France, Sweden and the US. An overview of all countries covered in this paper is provided in Fig. B.2. Individual country responses are derived from an LP time-series specification comprising the event variable, domestic research productivity, a subset of control variables, leads and lags of these regressors, and lagged values of the outcome variable. These regressions are conducted using both the original time-series data and data expressed as deviations from the cross-sectional mean (red lines), equivalent to regressions with time-effects (blue lines). The event plots in Fig. 4 show that the response of income inequality remains statistically significant even after controlling for the impact of common shocks (as captured by time dummies). The magnitude of the response is most pronounced for smaller economies. For instance, Sweden shows a 2% increase in top 5% income inequality five years after the event, while Canada and France exhibit increases around 1.5% and slightly below 1% for the US. Fig. B.2 indicates a similar pattern for other countries in our sample, namely Denmark, Finland, Italy, the Netherlands, and Portugal.

In sum, our exercise suggests that exogenous events that are likely to affect R&D productivity generate an inequality path that is consistent with the cointegration estimates. These findings support the view that R&D productivity allows us to identify the mechanisms of transmission of the effects of innovation. According to our long-run estimates (which represent our lower bound results), the yearly decline of 8.5% in domestic R&D productivity and 7.7% decline in foreign R&D productivity from 1920 to 2019 explain between 25% and 35% of the observed downward trend in income inequality over the past century.

7. How is innovation transmitted to inequality?

Our theoretical model predicts that the impact of domestic R&D on income inequality is ambiguous due to two opposing effects, viz., the interest-rate channel and the asset-value channel. In this section, we conduct a two-stage regression analysis to quantify the effects of domestic research productivity transmitted through these two conduits while controlling for foreign research productivity.



Notes: LP coefficient estimates (α_{1k}). Interval bands are at 95% confidence and are based on Eicker-Huber-White heteroskedasticity-robust standard errors. The red line and bands refer to original (not time demeaned data). The blue line and bands refer to time demeaned data, which is equivalent to using time dummies. The reported values correspond to the absolute percentage point change in inequality (Y-axis) over a 5-year horizon (X-axis). The model is regressed over the period 1970-2019. The following control variables are included in the estimates: domestic R&D productivity, Tobin's q, technological concentration, the share of the population with tertiary education, per capita income.

Fig. 4. Response of the top 5% income share to shocks to foreign R&D productivity: Individual country regressions.

In the first stage, we project domestic research productivity onto proxy variables for the two distinct channels. In the second stage, we regress the top 5% income share on the predicted values from these first-stage regressions to infer the inequality effects of the two forces. This exercise will help determine whether the coefficients of domestic research productivity are primarily influenced by the interest-rate channel (positive) or the creative destruction channel (negative).

For the asset value channel, we regress the capital-output ratio, K/Y, on both proxies for R&D productivity, while controlling for standard drivers of the capital-output ratio, such as the saving rate and per capita income growth. For the interest-rate channel, we regress the average rate of return of all assets, r, from Jordà et al. (2019a) on R&D productivity measures, the bank credit-GDP ratio (as a proxy for financial development), and per capita income growth. Similar to earlier works (see, e.g., De Loecker et al., 2020), this empirical strategy formalizes the idea that the two channels of innovation impact the share of aggregate income accruing to entrepreneurs ($r \times K/Y$).

This exercise follows two well-established streams in the literature. One stream investigates the determinants of the long-run movement in the capital-income ratio and the role played by the dynamics of the factor income shares (Piketty and Zucman, 2014; Madsen et al., 2018b). The prediction that the capital-income ratio is positively related to the rate of saving/investment and negatively related to income growth is also empirically supported by evidence in Madsen et al. (2021). The other stream of the literature studies the financial synchronization of advanced economies and relates recent co-movements of the interest rate to the slowdown in the productivity growth rate (see, e.g., Holston et al., 2017; Jordà et al., 2019b).

Note that, according to the theoretical framework, innovation by new entrants drives incumbents out of the market and depresses the value of assets (relative to wages) by dissipating existing innovation rents. Therefore, to capture the different effects of innovation by incumbents and new entrants, we multiply the overall R&D productivity, as used in the previous regressions, by the shares of total patents filed by recurrent and new applicants.[12]

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[12] Data on applications is from the Comprehensive Universe of U.S. Patents dataset (CUSP, Berkes, 2018), which provides information on disambiguated assignee names and country of origin, patent technological classes, citations, etc. for all patent applications filed at the USPTO from 1836 to 2016. The analysis is based on the

Table 5
Estimates of the channels (1920-2015, 16 countries).

	FIRST STAGE						**SECOND STAGE**
	Dep var: Capital-income ratio			*Dep var:* Rate of return on assets			*Dep var:* Top 5% income share
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Domestic R&D productivity	−0.040***			0.463***			
	(0.010)			(0.039)			
Domestic R&D productivity (incumbents)		0.034**	0.041***		0.066	−0.004	
		(0.015)	(0.015)		(0.059)	(0.062)	
Domestic R&D productivity (new entrants)		−0.072***	−0.080***		0.416***	0.432***	
		(0.015)	(0.015)		(0.058)	(0.057)	
Foreign R&D prod. (bilateral imports)	0.044***	0.066***	0.073***	0.200***	0.170***	0.126***	−0.113
	(0.010)	(0.010)	(0.010)	(0.041)	(0.039)	(0.042)	(0.084)
Total saving / GDP			−0.111***				
			(0.036)				
Real income growth			−0.003**			0.022**	
			(0.002)			(0.009)	
Bank credit / GDP						−0.464***	
						(0.099)	
Predicted rate of return on assets							0.172**
							(0.080)
Predicted capital-income ratio							0.939
							(0.655)
Obs.	1,536	1,511	1,485	1,273	1,269	1,258	1,468
R-squared	0.069	0.125	0.160	0.194	0.231	0.254	0.030

Notes: The estimates are obtained using the static FE-OLS estimator with Newey-West standard errors. The first-stage regressions incorporate country-specific fixed effects and common time dummies. In the second stage, the estimates include country-specific fixed effects and common correlated effects. Standard errors are bootstrapped with 100 replications in column (7). Column (7) uses predicted values from regressions in columns (2) and (5) as explanatory variables. The following five countries are excluded from the sample: Austria, Canada, Greece, Ireland, and New Zealand. ***, ** and * significant at 1, 5 and 10%, respectively.

The results are presented in Table 5. The second-stage estimates use standard errors bootstrapped with 100 replications. The table illustrates that domestic research productivity has a negative effect on the capital-income ratio, while foreign R&D productivity is positively associated with the dependent variable (column (1)). However, estimates in column (2) show that the former result is caused by the opposing effects exerted by the two components of R&D productivity, which are significantly positive for incumbents and significantly negative for new entrants. These effects are consistent with our Schumpeterian growth framework, where innovation by new entrants reduces the value of the overall stock of assets through the process of creative destruction. These results are robust to the inclusion of confounders, such as the saving rate and the rate of income growth (column (3)), with the impact of these controls being in line with earlier works.

In columns (4)-(6), we report the estimates for the relationship between the effects of domestic and foreign research productivity on the rate of return on assets. These variables are both positively related to the dependent variable as we would expect (column (4)). However, when domestic R&D productivity is decomposed into new entrants and incumbents (column (5)), we observe that the R&D productivity of new entrants is a significantly positive determinant of asset returns, while no effect can be traced for incumbents. The coefficient of R&D productivity remains unaffected by the inclusion of income growth and financial development as controls (column (6)).

Finally, column (7) reports the second-stage results based on the predicted values of the capital-income ratio and the rate of return on assets from the regressions in columns (2) and (5). These estimates indicate that the interest-rate channel is the main mechanism through which higher R&D productivity translates into higher income inequality. This finding is consistent with Moll et al. (2022), who study the distributional consequences of automation, showing that these new technologies would increase inequality by raising returns to wealth. Notably, the size of the predicted effect of the interest rate is larger than that found in the previous sections. This corroborates our interpretation of the reduced-form equation parameter for R&D productivity as the net impact of the two opposite forces.

The fact that the predicted value of the interest rate is found to be significantly associated with income inequality lends credit to the view that research productivity, being related to returns to innovation, is exogenous to income distribution and, hence, that the direction of causality is the one predicted by the theoretical framework. Indeed, it is highly implausible that the reverse mechanism is at work, i.e., that higher income inequality raises research productivity through a higher interest rate when controlling for financial development and other financial factors that usually determine firms' engagement in innovation activities.

FE-OLS estimator in which time dummies are included in the first-step regression, while common correlated effects are allowed for in the second step. The standard errors, robust to serial correlation and heteroskedasticity, are bootstrapped with 100 replications in the second-step regressions in order to account for the non-casual nature of the main regressors. Due to data constraints, this part of the analysis covers the period from 1920 to 2015 and includes only 16 countries. Specifically, it excludes Austria, Canada, Greece, Ireland, and New Zealand from the total of 21 countries.

8. Concluding remarks

In this paper, we show theoretically and empirically that the declining R&D productivity over the past century has significant income distributional consequences. Guided by a Schumpeterian growth framework, we show that the net impact of *domestic* research productivity on inequality is theoretically ambiguous due to two opposing forces, while *foreign* research productivity unambiguously has a positive effect on income inequality, operating solely through the interest-rate channel. Thus, for domestic productivity, whether the inequality effects are positive or negative becomes an empirical issue.

To resolve this theoretical ambiguity, we look at the long-run (cointegration) relationship between R&D productivity and income inequality using data from 21 OECD countries over the period 1920-2019. Furthermore, we conduct a local projection analysis, the results of which are largely consistent with the long-run regression. This analysis suggests a causal linkage from R&D productivity to income inequality. Finally, we employ a two-step regression procedure to quantify the impact of research productivity on income inequality through each of the two transmission channels. The results consistently show that research productivity plausibly causes inequality, with the interest-rate channel dominating the asset-value channel.

The inequality effect we have identified for R&D productivity is quantitatively important. Our most conservative estimates from our cointegration regressions show that the long-run income inequality elasticity of research productivity is 0.030 for domestic research productivity and 0.013 for foreign research productivity. These values are reasonably close to the short-run estimates obtained from the event analysis in Section 6. Based on these findings, we can infer that the annual declines of 8.5% in domestic R&D productivity and 7.7% in foreign R&D productivity from 1920 to 2019 contributed between 25% and 35% to the observed decrease in income inequality over the past century. In sum, our results have advanced the literature by showing that the prolonged, long-term decline in domestic and foreign research productivity in high-income countries can explain a substantial reduction in income inequality—a phenomenon that has long posed challenges for the inequality literature (Roine and Waldenström, 2009; Islam et al., 2018; Madsen et al., 2021).

Appendix A

In this Appendix, we provide further details of the theoretical set-up that were omitted from the paper for the sake of brevity.

A.1. Model description

Labor supply

Solving household x's intertemporal optimization problem yields the fraction of time devoted to work, $l_t^d(x) = 1 - \theta c_t^d(x)/w_t^d$. Hence, aggregate labor supply, $L_t^d \equiv \int_0^1 l_t^d(x)\mathrm{d}x$, can be written as:

$$L_t^d = 1 - \theta \frac{C_t^d}{w_t^d}, \tag{A.1}$$

where $C_t^d \equiv \int_0^1 c_t^d(x)\mathrm{d}x$ denotes aggregate consumption.

Gross outputs

Solving the profit-maximization problem yields the conditional demand functions for the two gross outputs, Y^{dd} and Y^{df}, namely:

$$Y_t^{dd} = \beta \frac{Y_t^d}{P_{yt}^{dd}}, \qquad Y_t^{df} = (1-\beta)\frac{Y_t^d}{P_{yt}^{df}}, \tag{A.2}$$

where P_{yt}^{dd} is the price of Y_t^{dd} and P_{yt}^{df} is the price of Y_t^{df}. Notice that the price index for the final good, Y_t^d, is normalized to 1 (numeraire) and is equal to $(P_{yt}^{dd})^{\beta}(P_{yt}^{df})^{1-\beta}$.

Profits and wage income

Since the monopolistic price in product line i is a constant markup over the marginal cost $w_t^d/(z^d)^{N_t^d(i)}$, the total profits earned by industry i's leader amount to:

$$\pi_t^d(i) = \pi_t^{dd}(i) + \pi_t^{fd}(i) = \left(\frac{\psi-1}{\psi}\right)\left[p_{xt}^{dd}(i)X_t^{dd}(i) + p_{xt}^{fd}(i)X_t^{fd}(i)\right] = \left(\frac{\psi-1}{\psi}\right)(P_{yt}^{dd}Y_t^{dd} + P_{yt}^{fd}Y_t^{fd}), \tag{A.3}$$

where the last equality of this equation follows from Eq. (4). The total amount of labor engaged in production in industry i is equal to $L_{xt}^d(i) = L_{xt}^{dd}(i) + L_{xt}^{fd}(i)$ and their remuneration is given by:

$$w_t^d L_{xt}^d(i) = w_t^d L_{xt}^{dd}(i) + w_t^d L_{xt}^{fd}(i) = \frac{p_{xt}^{dd}(i)X_t^{dd}(i) + p_{xt}^{fd}(i)X_t^{fd}(i)}{\psi} = \frac{P_{yt}^{dd}Y_t^{dd} + P_{yt}^{fd}Y_t^{fd}}{\psi}. \tag{A.4}$$

Eqs. (A.3) and (A.4) show that profits and wage income are identical for all industries.

Asset ownership and the innovation process

Since industry leaders obtain the same amount of profit, the value of an innovation, $v_t^d(i)$, in industry i in country d is $v_t^d(i) = v_t^d$ for all $i \in [0,1]$. Given that the distribution of financial assets across the two countries is indeterminate, following Dinopoulos and Segerstrom (2010) and Chu et al. (2015), we make the assumption that the property shares of monopolistic firms in a country are owned only by domestic households.[13] Hence, the market value of an innovation is equal to the total value of financial assets owned by domestic households, namely $a_t^d = v_t^d$.

There is free entry in the R&D sector. Therefore, whenever this sector is active, expected profits must be equal to zero, so that:

$$v_t^d = \frac{D_t^d \Omega_t^d}{\vartheta^d}. \tag{A.5}$$

The familiar no-arbitrage condition for v_t^d equates the real interest rate, r_t^d, to the asset return per unit of asset, that is:

$$r_t^d = \frac{\pi_t^d + \dot{v}_t^d - \lambda_t^d v_t^d}{v_t^d}, \tag{A.6}$$

which shows that the asset return is the sum of monopolistic profits, π_t^d, and capital gain, $\dot{v}_t^d$, minus the expected capital loss, $\lambda_t^d v_t^d$, due to creative destruction.

A.2. Equilibrium and the dynamics of the aggregate economy

Here, we delve deeper into the model solution, providing comprehensive insights into the dynamics of the aggregate economy.

Definition of the equilibrium

An equilibrium is a time path of allocations and a time path of prices such that, at each instant of time, the following conditions must hold:

1. Household x in the domestic country chooses $\{c_t^d(x), l_t^d(x)\}$ to maximize $U^d(x)$ subject to the asset-accumulation constraint taking $\{r_t^d, w_t^d\}$ as given;
2. Household x in the foreign country chooses $\{c_t^f(x), l_t^f(x)\}$ to maximize $U^f(x)$ subject to the asset-accumulation constraint taking $\{r_t^f, w_t^f\}$ as given;
3. Competitive final-good firms in the domestic country produce $\{Y_t^d\}$ to maximize profits taking $\{P_{yt}^{dd}, P_{yt}^{df}\}$ as given;
4. Competitive final-good firms in the foreign country produce $\{Y_t^f\}$ to maximize profits taking $\{P_{yt}^{ff}, P_{yt}^{fd}\}$ as given;
5. Competitive firms in the domestic country produce gross outputs $\{Y_t^{dd}, Y_t^{df}\}$ to maximize profits taking $\{P_{yt}^{dd}, P_{yt}^{df}, p_{xt}^{dd}, p_{xt}^{df}\}$ as given;
6. Competitive firms in the foreign country produce gross outputs $\{Y_t^{ff}, Y_t^{fd}\}$ to maximize profits taking $\{P_{yt}^{ff}, P_{yt}^{fd}, p_{xt}^{ff}, p_{xt}^{fd}\}$ as given;
7. Monopolistic intermediate-good firm $i \in [0,1]$ in the domestic country produces $\{X_t^{dd}(i), X_t^{fd}(i)\}$ and chooses $\{p_{xt}^{dd}(i), p_{xt}^{fd}(i)\}$ to maximize profits taking $\{w_t^d\}$ as given;
8. Monopolistic intermediate-good firm $j \in [0,1]$ in the foreign country produces $\{X_t^{ff}(i), X_t^{df}(i)\}$ and chooses $\{p_{xt}^{ff}(j), p_{xt}^{df}(j)\}$ to maximize profits taking $\{w_t^f\}$ as given;
9. Competitive R&D entrepreneur $\imath \in [0,1]$ in the domestic country devotes $\{R_t^d(\imath)\}$ units of final goods to R&D to maximize expected profits taking $\{v_t^d\}$ as given;
10. Competitive R&D entrepreneur $\imath \in [0,1]$ in the foreign country devotes $\{R_t^f(\imath)\}$ units of final goods to R&D to maximize expected profits taking $\{v_t^f\}$ as given;
11. The market-clearing conditions for final goods hold in the two countries such that $Y_t^d = C_t^d + R_t^d$ and $Y_t^f = C_t^f + R_t^f$;
12. The market-clearing conditions for labor hold in the two countries such that $L_t^d = \int_0^1 L_{xt}^d(i)\mathrm{d}i$ and $L_t^f = \int_0^1 L_{xt}^f(i)\mathrm{d}i$;
13. The total value of households' assets equals the value of monopolistic firms in each country such that $v_t^d = a_t^d = \int_0^1 a_t^d(x)\mathrm{d}x$ and $v_t^f = a_t^f = \int_0^1 a_t^f(x)\mathrm{d}x$;
14. The total value of trade in intermediate goods is balanced such that $P_{yt}^{fd} Y_t^{fd} = P_{yt}^{df} Y_t^{df}$.

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[13] This assumption is consistent with Feldstein and Horioka (1980) who show the existence of a close relationship between domestic investment and saving using OECD data. See French and Poterba (1991) and Tesar and Werner (1995) for additional supporting evidence regarding the tendency to prioritize domestic assets in investment portfolios.

Aggregate technology

Substituting X_t^{dd} from (5) into Y_t^{dd}, we get $Y_t^{dd} = Z_t^d L_{xt}^{dd}$, where Z_t^d denotes aggregate technology in the home country, which is defined as:

$$Z_t^d \equiv \exp\left(\int_0^1 N_t^d(i)\mathrm{d}i \ln z^d\right) = \exp\left(\int_0^t \lambda_s^d \mathrm{d}s \ln z^d\right),$$

noting that the second equality of this equation applies the law of large numbers. Differentiating the log of Z_t^d with respect to t gives the home country's growth rate of aggregate technology, namely:

$$\frac{\dot{Z}_t^d}{Z_t^d} = \lambda_t^d \ln z^d = \vartheta^d \frac{R_t^d}{\Omega_t^d D_t^d} \ln z^d.$$

Similarly, substituting $X_t^{df} = (z^f)^{N_t^f(j)} L_{xt}^{df}(j)$ into Y^{df} yields $Y_t^{df} = Z_t^f L_{xt}^{df}$, where the foreign country's aggregate technology is defined as $Z_t^f \equiv \exp\left(\int_0^1 N_t^f(j)\mathrm{d}j \ln z^f\right) = \exp\left(\int_0^t \lambda_s^f \mathrm{d}s \ln z^f\right)$. The growth rate of the foreign country's aggregate technology is obtained by differentiating the log of Z_t^f with respect to t, that is:

$$\frac{\dot{Z}_t^f}{Z_t^f} = \lambda_t^f \ln z^f = \vartheta^f \frac{R_t^f}{\Omega_t^f D_t^f} \ln z^f.$$

Equilibrium labor allocation

Given the profit-maximizing price in each industry, the price indices for Y_t^{dd} and Y_t^{fd} can be written as $P_{yt}^{dd} = P_{yt}^{fd} = \psi w_t^d / Z_t^d$. Similarly, the price indices for Y_t^{ff} and Y_t^{df} are equal to $P_{yt}^{ff} = P_{yt}^{df} = \psi w_t^f / Z_t^f$. Using the conditional demand functions in country h for domestic and foreign gross outputs (A.2) yields:

$$\frac{P_{yt}^{dd} Y_t^{dd}}{\beta} = \frac{P_{yt}^{df} Y_t^{df}}{1-\beta} = \frac{P_{yt}^{fd} Y_t^{fd}}{1-\beta}, \tag{A.7}$$

where the second equality of Eq. (A.7) exploits the balanced-trade condition $P_{yt}^{fd} Y_t^{fd} = P_{yt}^{df} Y_t^{df}$. Recalling that $Y_t^{dd} = Z_t^d L_{xt}^{dd}$ and $Y_t^{fd} = Z_t^d L_{xt}^{fd}$, we easily get:

$$L_{xt}^{fd} = \frac{(1-\beta)}{\beta} L_{xt}^{dd}.$$

Combining this equation with the labor-market clearing condition for the domestic country $L_{xt}^{dd} + L_{xt}^{fd} = L_t^d$ yields $L_{xt}^{dd} = \beta L_t^d$ and $L_{xt}^{fd} = (1-\beta) L_t^d$. Following a similar procedure for the foreign country, we get $L_{xt}^{ff} = \beta L_t^f$ and $L_{xt}^{df} = (1-\beta) L_t^f$. Substituting L_{xt}^{dd} into Y_t^{dd} and L_{xt}^{df} into Y_t^{df} yields $Y_t^{dd} = \beta Z_t^d L_t^d$ and $Y_t^{df} = (1-\beta) Z_t^f L_t^f$. Finally, inserting these results into Eq. (3), final output in the domestic economy can be written as:

$$Y_t^d = (Z_t^d L_t^d)^\beta (Z_t^f L_t^f)^{1-\beta} = D_t^d \Omega_t^d. \tag{A.8}$$

Dynamics of the aggregate economy

Substituting the balanced-trade condition $P_{yt}^{fd} Y_t^{fd} = P_{yt}^{df} Y_t^{df}$ into Eqs. (A.3) and (A.4) gives:

$$\pi_t^d = \left(\frac{\psi - 1}{\psi}\right)(P_{yt}^{dd} Y_t^{dd} + P_{yt}^{df} Y_t^{df}) = \left(\frac{\psi - 1}{\psi}\right) Y_t^d, \tag{A.9}$$

$$w_t^d L_t^d = \frac{P_{yt}^{dd} Y_t^{dd} + P_{yt}^{df} Y_t^{df}}{\psi} = \frac{Y_t^d}{\psi}, \tag{A.10}$$

where the second equality of (A.9) and (A.10) follows from (A.2). Using Eqs. (A.5), (A.8) and (A.9) and recalling that $v_t^d = a_t^d$ we get:

$$\frac{\dot{a}_t^d}{a_t^d} = \frac{\dot{v}_t^d}{v_t^d} = \frac{\dot{D}_t^d}{D_t^d} + \frac{\dot{\Omega}_t^d}{\Omega_t^d} = \frac{\dot{Y}_t^d}{Y_t^d} = \frac{\dot{\pi}_t^d}{\pi_t^d}, \tag{A.11}$$

which shows that $\{a_t^d, v_t^d, Y_t^d, \pi_t^d\}$ grows at the same rate. Next, we define the transformed variable $\Sigma_t^d \equiv C_t^d / (D_t^d \Omega_t^d)$ and show its stationarity. Inserting the market-clearing condition for final goods $Y_t^d = C_t^d + R_t^d$ into Eq. (6) gives:

$$\lambda_t^d = \vartheta^d \left(\frac{Y_t^d - C_t^d}{D_t^d \Omega_t^d} \right) = \vartheta^d (1 - \Sigma_t^d), \tag{A.12}$$

where the second equality uses $Y_t^d = D_t^d \Omega_t^d$ by Eq. (A.8). As Eq. (A.12) shows, the dynamics of λ_t^d are entirely determined by Σ_t^d. Taking the log of Σ_t^d and differentiating it with respect to t gives:

$$\frac{\dot{\Sigma}_t^d}{\Sigma_t^d} = \frac{\dot{C}_t^d}{C_t^d} - \frac{\dot{D}_t^d}{D_t^d} - \frac{\dot{\Omega}_t^d}{\Omega_t^d} = r_t^d - \rho - \frac{\dot{v}_t^d}{v_t^d}, \tag{A.13}$$

where the second equality uses the Euler equation (2) and the fact that $\dot{v}_t^d / v_t^d = \dot{D}_t^d / D_t^d + \dot{\Omega}_t^d / \Omega_t^d$ by Eq. (A.11). Substituting r_t^d from (A.6) into (A.13) and noticing that $\pi_t^d = v_t^d \vartheta^d (\psi - 1)/\psi$ by Eqs. (A.8), (A.9) and (A.5), we get:

$$\frac{\dot{\Sigma}_t^d}{\Sigma_t^d} = \frac{(\psi - 1)}{\psi} \vartheta^d - \lambda_t^d - \rho. \tag{A.14}$$

Then, inserting λ_t^d from (A.12) into (A.14) yields a one-dimensional differential equation for Σ_t^d, namely:

$$\frac{\dot{\Sigma}_t^d}{\Sigma_t^d} = \vartheta^d \Sigma_t^d - \rho - \frac{\vartheta^d}{\psi}. \tag{A.15}$$

Since the coefficient of Σ_t^d in (A.15), namely ϑ^d, is positive, the dynamics of Σ_t^d are characterized by saddle-point stability. Thus, Σ_t^d immediately jumps to its non-zero steady-state value given by $\Sigma^d = \rho/\vartheta^d + 1/\psi$. Using this result in (A.12) implies that the steady-state arrival rate of innovation in the domestic country amounts to $\lambda^d = \vartheta^d (\psi - 1)/\psi - \rho$. A similar exercise yields the steady-state arrival rate of innovation in the foreign country, namely $\lambda^f = \vartheta^f (\psi - 1)/\psi - \rho$. Given the stationarity of Σ_t^d, Eq. (A.8) implies that C_t^d must grow at the same rate as Y_t^d.

We finally prove that $\Omega_t^d \equiv (L_t^d)^\beta (L_t^f)^{1-\beta}$ is also stationary. Rewriting Eq. (A.1) as $\theta C_t^d = w_t^d (1 - L_t^d)$ and then dividing both sides of this equation by Y_t^d yields:

$$\theta \frac{C_t^d}{Y_t^d} = \theta \Sigma^d = \frac{w_t^d}{Y_t^d} - \frac{w_t^d L_t^d}{Y_t^d}, \tag{A.16}$$

where the first equality uses the fact that $Y_t^d = D_t^d \Omega_t^d$ by Eq. (A.8). Inserting $w_t^d L_t^d$ from (A.10) into (A.16) yields $w_t^d / Y_t^d = \theta \Sigma^d + 1/\psi$, which implies that $\dot{w}_t^d / w_t^d = \dot{Y}_t^d / Y_t^d$. Then, taking the log of (A.10) and differentiating the resulting equation with respect to t yields:

$$\frac{\dot{L}_t^d}{L_t^d} = \frac{\dot{Y}_t^d}{Y_t^d} - \frac{\dot{w}_t^d}{w_t^d} = 0,$$

which shows that labor supply in the domestic economy, L_t^d, must be stationary. The latter takes the following value:

$$L_t^d = L^d = 1 - \theta \frac{C_t^d}{w_t^d} = 1 - \theta \frac{C_t^d}{Y_t^d} \frac{Y_t^d}{w_t^d} = 1 - \theta \frac{\Sigma^d}{\left(\theta \Sigma^d + 1/\psi\right)} = \frac{1}{1 + \theta + \theta \rho \psi / \vartheta^d}. \tag{A.17}$$

Following a similar exercise for the foreign economy, it is possible to show the stationarity of L_t^f. We then conclude that Ω_t^d is stationary. Using these results in Eq. (A.11), we finally get that $\{a_t^d, v_t^d, Y_t^d, \pi_t^d, C_t^d, w_t^d\}$ grow at the same rate as the aggregate index of R&D difficulty, D_t^d.

A.3. Wealth and income distributions

We now explore the implications of the model regarding wealth and income distributions.

Wealth distribution

We now show that the distribution of wealth is stationary on the BGP. The value of wealth in the domestic economy evolves according to:

$$\dot{a}_t^d = r_t^d a_t^d + w_t^d L_t^d - C_t^d. \tag{A.18}$$

Combining (1) with (A.18), the law of motion of $\phi_{at}^d(x) \equiv a_t^d(x)/a_t^d$ can be written as:

$$\dot{\phi}_{at}^d(x) = \frac{w_t^d L_t^d}{a_t^d} \phi_{lt}^d(x) - \frac{C_t^d}{a_t^d} \phi_{ct}^d(x) - \frac{(w_t^d L_t^d - C_t^d)}{a_t^d} \phi_{at}^d(x), \tag{A.19}$$

where $\phi_{lt}^d(x) \equiv l_t^d(x)/L_t^d$ and $\phi_{ct}^d(x) \equiv c_t^d(x)/C_t^d$. Using Eqs. (A.5), (A.8), (A.10) and $v_t^d = a_t^d$ and recalling that the aggregate economy is always on the BGP along which $\Sigma_t^d \equiv C_t^d/(D_t^d \Omega_t^d) = \Sigma^d = \rho/\vartheta^d + 1/\psi$, after some rearranging, we get:

$$\frac{w_t^d L_t^d}{a_t^d} = \frac{\vartheta^d}{\psi}, \qquad \frac{C_t^d}{a_t^d} = \rho + \frac{\vartheta^d}{\psi}. \tag{A.20}$$

Moreover, using Eq. (A.1), we can express $\phi_{lt}^d(x)$ as:

$$\phi_{lt}^d(x) = \frac{w_t^d - \theta c_t^d(x)}{w_t^d - \theta C_t^d} = \frac{\frac{w_t^d}{Y_t^d} - \theta \frac{C_t^d}{Y_t^d}\phi_{ct}^d(x)}{\frac{w_t^d}{Y_t^d} - \theta \frac{C_t^d}{Y_t^d}} = \frac{\theta\psi}{\vartheta^d}\left(\rho + \frac{\vartheta^d}{\psi}\right)[1 - \phi_{ct}^d(x)] + 1, \tag{A.21}$$

where the third equality of (A.21) uses the fact that $w_t^d/Y_t^d = \theta\Sigma^d + 1/\psi$ and $C_t^d/Y_t^d = \Sigma^d$. Using Eqs. (A.20) and (A.21) in (A.19) and noticing that $\phi_{ct}^d(x) = \phi_{c0}^d(x)$ for all $t > 0$ by Eq. (2) yields:

$$\dot{\phi}_{at}^d(x) = \rho\phi_{at}^d(x) + \frac{\vartheta^d}{\psi} + \left(\rho + \frac{\vartheta^d}{\psi}\right)\left\{\left[\theta(1 - \phi_{c0}^d(x)\right] - \phi_{c0}^d(x)\right\}. \tag{A.22}$$

The coefficient of ϕ_{at}^d, namely ρ, is positive. Thus, the only solution of the differential equation (A.22) consistent with long-run stability is $\dot{\phi}_{at}^d(x) = 0$ for all t. Imposing this condition gives the steady-state value of $\phi_{ct}^d(x)$, namely:

$$\phi_{c0}^d(x) = \frac{(\theta+1)\left(\rho + \frac{\vartheta^d}{\psi}\right) + \rho\left[\phi_{a0}^d(x) - 1\right]}{(1+\theta)\left(\rho + \frac{\vartheta^d}{\psi}\right)}.$$

We therefore conclude that, for every household x, its asset share in the domestic country, $\phi_{at}^d(x)$, is exogenously determined at time 0, namely $\phi_{at}^d(x) = \phi_{a0}^d(x)$ for all t (stationarity of the wealth distribution).

Income distribution

Since the wealth distribution is stationary, $\dot{a}_t^d(x)/a_t^d(x) = \dot{a}_t^d/a_t^d = g^d$ for all $x \in [0, 1]$. Using this result, we can write the budget constraint (1) as $c_t^d(x) = (r_t^d - g^d)a_t^d(x) + w_t^d l_t^d(x)$. Inserting $c_t^d(x)$ into household x's labor supply, $l_t^d(x) = 1 - \theta c_t^d(x)/w_t^d$, labor income becomes:

$$w_t^d l_t^d(x) = \frac{w_t^d - \theta(r_t^d - g^d)a_t^d(x)}{1+\theta}, \tag{A.23}$$

which shows that richer households earn lower labor income as they supply less labor (since $r_t^d > g^d$). It is important to note that labor income inequality in the model originates from endogenous labor supply. Since households' labor supply is a decreasing function of their consumption share, which, in turn, depends positively on their wealth share, asset-wealthy households earn lower labor income. Using Eq. (A.23), household x's income, $I_t^d(x)$, can be expressed as:

$$I_t^d(x) = \frac{(r_t^d + \theta g^d)a_t^d(x) + w_t^d}{1+\theta}, \tag{A.24}$$

which implies that the aggregate level of income amounts to $I_t^d = [(r_t^d + \theta g^d)a_t^d + w_t^d]/(\theta+1)$. The term θg^d in Eq. (A.24) captures the impact on labor income of endogenous labor supply: a higher g^d increases the household's labor supply and hence its labor income, with an effect that is stronger for asset-wealthy households. To put it simply, households with substantial assets tend to be more receptive to an increase in the growth rate when it comes to their labor supply. Using these results together with the fact that $r_t^d = r^d = g^d + \rho$, the share of income earned by household x, $\phi_{It}^d(x) \equiv I_t^d(x)/I_t^d$, becomes:

$$\phi_{It}^d(x) = \frac{[r^d(1+\theta) - \rho\theta]a_t^d(x) + w_t^d}{[r^d(1+\theta) - \rho\theta]a_t^d + w_t^d} = \frac{[r^d(1+\theta) - \rho\theta]a_t^d\phi_{a0}^d(x) + w_t^d}{[r^d(1+\theta) - \rho\theta]a_t^d + w_t^d}, \tag{A.25}$$

where the second equality uses the stationarity of the wealth distribution, that is $\phi_{at}^d(x) = \phi_{a0}^d(x)$ for all t. The standard deviation of the distribution of income share amounts to:

$$\sigma_{It}^d = \sqrt{\int_0^1 [\phi_{It}^d(x) - 1]^2 \mathrm{d}x} = \frac{[r^d(1+\theta) - \rho\theta]a_t^d/w_t^d}{[r^d(1+\theta) - \rho\theta]a_t^d/w_t^d + 1}\sigma_a^d,$$

with the interest rate, r^d, equal to $g^d + \rho$, the economy's growth rate, g^d, given by Eq. (7) and the asset-wage ratio, a_t^d/w_t^d, equal to:

$$\frac{a_t^d}{w_t^d} = \frac{a_t^d/Y_t^d}{w_t^d/Y_t^d} = \frac{1/\vartheta^d}{\theta\Sigma^d + 1/\psi} = \frac{1/\vartheta^d}{\theta\rho/\vartheta^d + (1+\theta)/\psi} = \frac{1}{\theta\rho + (1+\theta)\vartheta^d/\psi}. \tag{A.26}$$

The second equality in (A.26) is obtained from the relationship $a_t^d = v_t^d = D_t^d\Omega_t^d/\vartheta^d = Y_t^d/\vartheta^d$, as described by Eqs. (A.5) and (A.8), combined with the observation that on the BGP, the wage-income ratio w_t^d/Y_t^d equals $\theta\Sigma^d + 1/\psi$. Notice that a higher ϑ^d

lowers both the value of assets relative to income, a_t^d/Y_t^d, and the wage-income ratio, w_t^d/Y_t^d. As shown in (A.26), the former effect is greater than the latter one, thus causing the asset-wage ratio to fall with ϑ^d (asset-value effect). Notice that the asset-wage ratio in the domestic economy is independent of foreign R&D productivity. This result depends on the assumption that $a_t^d = v_t^d$, which implies that monopolistic firms created by domestic entrepreneurs' innovations are owned by domestic households.

Gini coefficient of income

Let us sort households in ascending order of wealth and income. The Gini coefficients of wealth and income are defined respectively as:

$$\sigma_{at}^{dG} \equiv 1 - 2\int_0^1 \mathcal{L}_{at}^d(\chi)\mathrm{d}\chi, \qquad \sigma_{It}^{dG} \equiv 1 - 2\int_0^1 \mathcal{L}_{It}^d(\chi)\mathrm{d}\chi,$$

where $\mathcal{L}_{at}^d(\chi)$ and $\mathcal{L}_{It}^d(\chi)$ are the Lorenz curves of wealth and income respectively, namely:

$$\mathcal{L}_{at}^d(\chi) \equiv \frac{\int_0^\chi a_t^d(x)\mathrm{d}x}{\int_0^1 a_t^d(x)\mathrm{d}x} = \int_0^\chi \phi_{at}^d(x)\mathrm{d}x, \qquad \mathcal{L}_{It}^d(\chi) \equiv \frac{\int_0^\chi I_t^d(x)\mathrm{d}x}{\int_0^1 I_t^d(x)\mathrm{d}x} = \int_0^\chi \phi_{It}^d(x)\mathrm{d}x.$$

Substituting $\phi_{It}^d(x)$ into the expression for $\mathcal{L}_{It}^d(\chi)$ using Eq. (A.25), we get:

$$\mathcal{L}_{It}^d(\chi) = \frac{[r^d(1+\theta) - \rho\theta]a_t^d \int_0^\chi \phi_{at}^d(x)\mathrm{d}x + w_t^d\chi}{[r^d(1+\theta) - \rho\theta]a_t^d + w_t^d} = \frac{[r^d(1+\theta) - \rho\theta]a_t^d \mathcal{L}_{a0}^d(\chi) + w_t^d\chi}{[r^d(1+\theta) - \rho\theta]a_t^d + w_t^d},$$

where the second equality exploits the fact that the wealth distribution is stationary. Then, substituting $\mathcal{L}_{It}^d(\chi)$ into the Gini index of income inequality, σ_{It}^{dG}, and rearranging terms yields:

$$\sigma_{It}^{dG} = \frac{[r^d(1+\theta) - \rho\theta]a_t^d/w_t^d}{[r^d(1+\theta) - \rho\theta]a_t^d/w_t^d + 1}\sigma_a^{dG},$$

where σ_a^{dG} denotes the Gini coefficient of wealth at time 0.

Share of income of the top ϱ households

Let us define the shares of wealth and income of the top ϱ households respectively as:

$$S_{at}^{d\varrho} \equiv \int_{1-\varrho}^1 \phi_{at}^d(x)\mathrm{d}x, \qquad S_{It}^{d\varrho} \equiv \int_{1-\varrho}^1 \phi_{It}^d(x)\mathrm{d}x.$$

Substituting $\phi_{It}^d(x)$ from Eq. (A.25) into $S_{It}^{d\varrho}$ and rearranging terms yields:

$$S_{It}^{d\varrho} = \frac{[r^d(1+\theta) - \rho\theta]a_t^d S_{at}^{d\varrho} + w_t^d\varrho}{[r^d(1+\theta) - \rho\theta]a_t^d + w_t^d} = \frac{[r^d(1+\theta) - \rho\theta]a_t^d/w_t^d}{[r^d(1+\theta) - \rho\theta]a_t^d/w_t^d + 1}(S_{at}^{d\varrho} - \varrho) + \varrho,$$

which shows that the top ϱ income share is increasing in asset returns, r^d, and in the asset-wage ratio, a_t^d/w_t^d, provided that the share of wealth of the top ϱ households, $S_{at}^{d\varrho}$, is greater than ϱ. The latter condition typically holds due to the high concentration of wealth observed in the data.

A.4. Calibration

Since, in the model, a change in the domestic R&D efficiency has an ambiguous impact on income inequality, we calibrate our two-country growth framework to gain insights into the sign of this relationship. To this end, we derive a condition enabling the comparison of the two effects. Inserting g^d from Eq. (7) and a_t^d/w_t^d from Eq. (A.26) into Eq. (8) and then differentiating σ_{It}^d with respect to ϑ^d yields:

$$\frac{\partial\sigma_{It}^d}{\partial\vartheta^d} > 0 \iff \beta > \tilde{\beta} \equiv \frac{\rho\psi + (1+\theta)\ln z^f\left[(\psi-1)\vartheta^f - \rho\psi\right]}{\rho\psi(\theta\psi+1)\ln z^d + (1+\theta)\ln z^f\left[(\psi-1)\vartheta^f - \rho\psi\right]}, \tag{A.27}$$

which suggests that the positive interest-rate effect dominates the negative asset-value effect, provided that the importance of imported goods in domestic final-good production is relatively low (β relatively high). This establishes a positive relationship between income inequality and domestic innovation.

Table A.1
Calibrated parameter values.

ρ	ψ	β	ϑ^d	z^d	ϑ^f	z^f	θ	$\tilde{\beta}$
0.05	1.10	0.95	0.77	1.53	0.72	1.66	1.89	0.81

Table A.2
Effect of changing ψ and ρ on $\tilde{\beta}$.

		$\tilde{\beta}$	
$\rho =$	0.03	0.04	0.05
$\psi = 1.10$	0.59	0.70	0.81
$\psi = 1.15$	0.41	0.48	0.56
$\psi = 1.20$	0.31	0.37	0.43

Using aggregate data from 1985 to 2019, we envisage a world that consists of the US and a weighted combination of 6 other innovation-intensive countries weighted by their GDP in purchasing power parity: Canada, France, Germany, Italy, Japan, and the UK. The model features the following parameters: $\{\rho, \psi, \beta, \vartheta^d, z^d, \vartheta^f, z^f, \theta\}$. We set the discount rate ρ to 0.05 following Acemoglu and Akcigit (2012) and the markup, ψ, to 1.10, which is in the lower range of the estimates of Hall (2018) and Barkai (2020).[14] We calibrate $\{\beta, \vartheta^d, z^d\}$ using the following moments for the US economy. The average US imports-income ratio is estimated as imports from the six-country sample to the US relative to the US GDP (approximately 5%) and we use this moment to calibrate the parameter β.[15]

Substituting $D_t^d \Omega_t^d$ from (A.8) into (6) and rearranging terms allows us to express the share of R&D expenditure in total GDP as:

$$\frac{R^d}{Y^d} = \frac{\lambda^d}{\vartheta^d},$$

which is set to 2.6%.[16] Inserting $\lambda^d = \vartheta^d(\psi - 1)/\psi - \rho$ into the former equation yields an R&D productivity parameter of $\vartheta^d = 0.77$. This results in an arrival rate of innovation of 2%. The average annual growth rate of total factor productivity (TFP) has been 0.86%,[17] which allows us to pin down the value of the step size of innovation, namely $z^d = \exp[(\frac{\dot{Z}^d}{Z^d})/\lambda^d] = 1.53$. Following the same procedure for the foreign country,[18] we get an R&D productivity parameter of $\vartheta^f = 0.7$ and a step size of innovation of $z^f = 1.64$. As for the leisure parameter, θ, we calibrate it by matching the average fraction of time devoted to labor supply, L^d in Eq. (A.17), to the value of 0.33, which gives $\theta = 1.89$. Inserting all these values in (A.27), we calculate $\tilde{\beta}$. Table A.1 summarizes the calibrated parameter values.

Based on these parameter values, since $\beta > \tilde{\beta}$, the positive interest-rate effect dominates the negative asset-value effect, implying that an increase in domestic R&D productivity leads to an increase in income inequality. In this numerical exercise, we consider a conservatively low markup rate, ψ, and a relatively high discount rate, ρ. In Table A.2, we report results for $\rho \in \{0.03, 0.04, 0.05\}$ and $\psi \in \{1.10, 1.15, 1.20\}$.

Table A.2 shows that considering a larger ψ or a smaller ρ, relative to the baseline values, leads to an even lower $\tilde{\beta}$, which strengthens the positive long-run relationship between income inequality and domestic innovation. Therefore, we view the benchmark results under $\rho = 0.05$ and $\psi = 1.10$ as conservative.

Appendix B

B.1. Shocks to foreign R&D productivity

Here, we illustrate the response of the top 5% income share to peak increases in foreign research productivity. We present both the response for the pool of countries (Fig. B.1) and the responses observed in individual countries (Fig. B.2).

Appendix C. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jedc.2024.104924.

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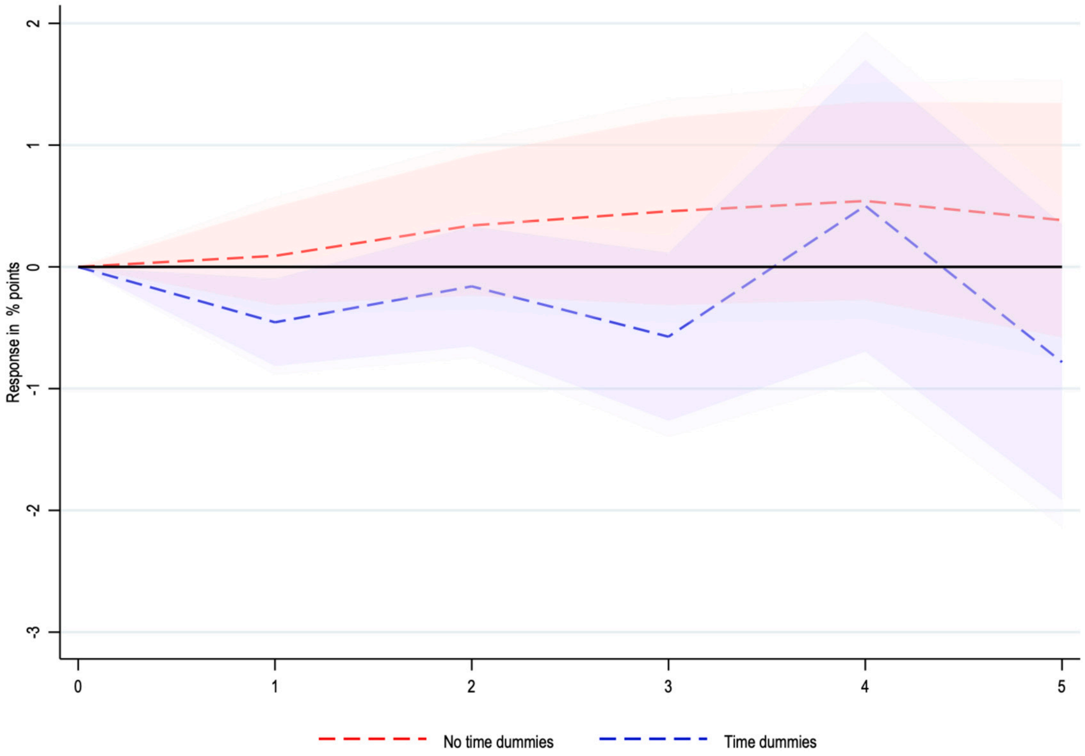
[14] Using data on the US economy, these papers focus on the increase in markups since the early 1980s. See also De Loecker et al. (2020) who document a steady increase in the average markup in the US since 1980, mostly due to a reallocation of resources towards high markup firms.

[15] Data source: U.S. Bureau of Economic Analysis, international data.

[16] Data source: OECD (2021), Gross domestic spending on R&D (indicator).

[17] Data source: OECD (2021), Multifactor productivity (indicator).

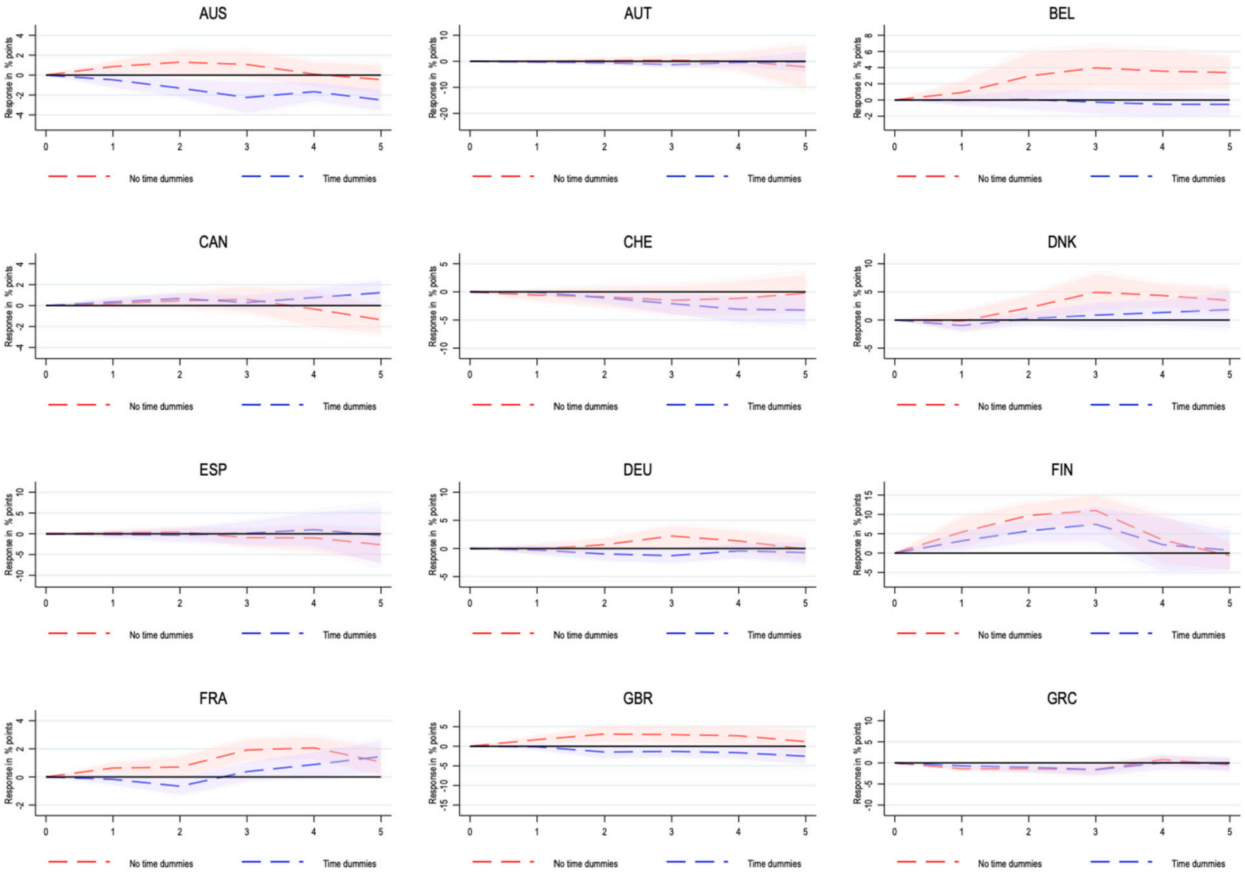
[18] We use an average R&D share of GDP of 2.22% and an average TFP growth rate of 0.82% (Data source: OECD 2021).



Notes: LP coefficient estimates (α_{1k}). Bands in dark and light red (blue) toning signify 90% and 95% confidence intervals based on Eicker-Huber-White heteroskedasticity-robust standard errors. The reported values correspond to the absolute percentage point change in inequality (Y-axis) over a 5-year horizon (X-axis). The model is regressed over the period 1970-2019. The following control variables are used in the regressions: domestic R&D productivity, Tobin's q, the share of the population with tertiary education, per capita income, the share of tax revenues in GDP, union membership.

Fig. B.1. Response of the top 5% income share to shocks to foreign R&D productivity (pooled estimates).

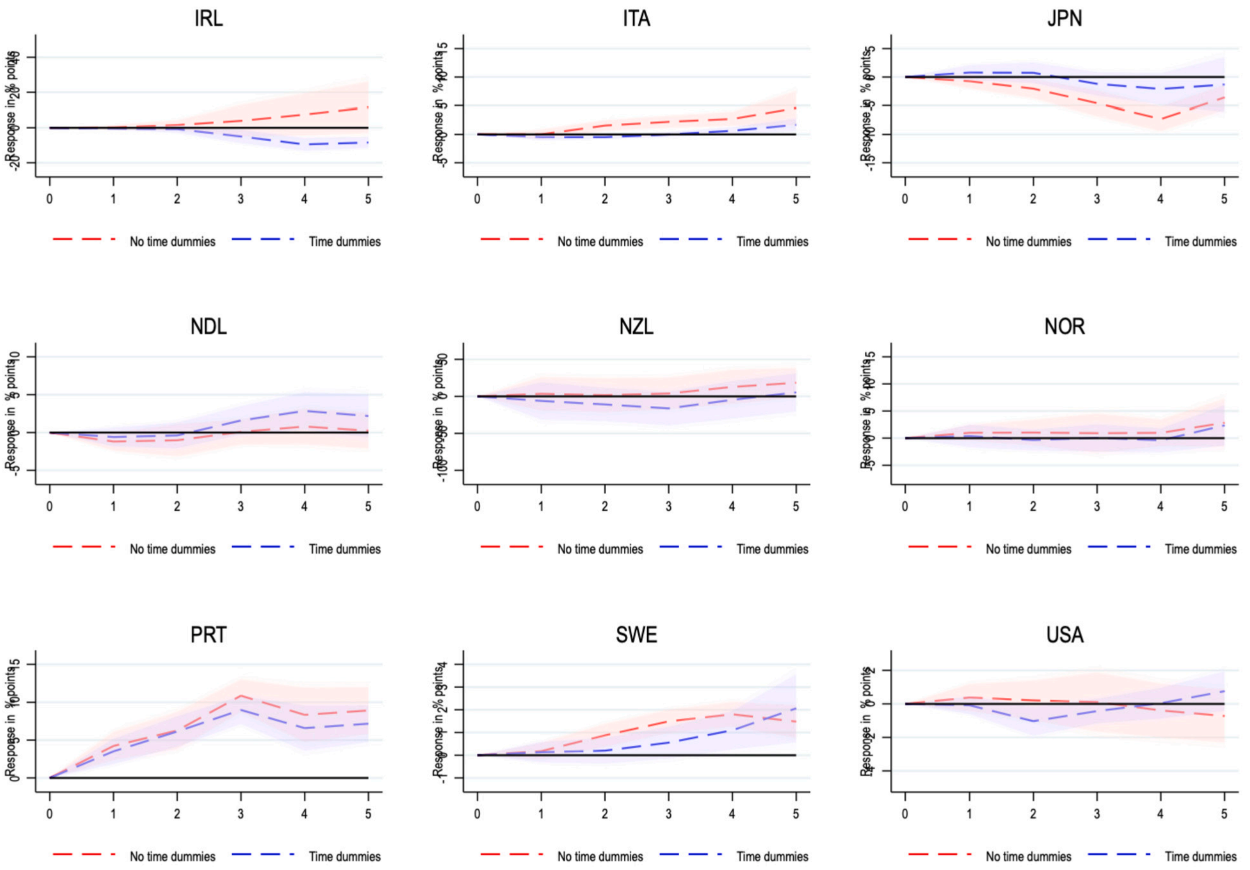
(A)



Notes: LP coefficient estimates (α_{1k}). Interval bands are at a 95% confidence level and are based on Eicker-Huber-White heteroskedasticity-robust standard errors. The red line and bands refer to the original (not time-demeaned) data. The blue line and bands refer to time-demeaned data, which is equivalent to using time dummies. The reported values correspond to the absolute percentage point change in inequality (Y-axis) over a 5-year horizon (X-axis). The model is regressed over the period 1970-2019. The following control variables are included in the estimates: domestic R&D productivity, Tobin's q, technological concentration, the share of the population with tertiary education, per capita income.

Fig. B.2. (A) Response of the top 5% income share to shocks to foreign R&D productivity (individual country regressions). (B) Response of the top 5% income share to shocks to foreign R&D productivity (individual countries).

(B)



Notes: LP coefficient estimates (α_{1k}). Interval bands are at a 95% confidence level and are based on Eicker-Huber-White heteroskedasticity-robust standard errors. The red line and bands refer to the original (not time-demeaned) data. The blue line and bands refer to time-demeaned data, which is equivalent to using time dummies. The reported values correspond to the absolute percentage point change in inequality (Y-axis) over a 5-year horizon (X-axis). The model is regressed over the period 1970-2019. The following control variables are included in the estimates: domestic R&D productivity, Tobin's q, technological concentration, the share of the population with tertiary education, per capita income.

Fig. B.2. (*continued*)

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