Innovation, Income Inequality and Long-run Growth

Jakob Madsen[◇] Antonio Minniti[♠] Francesco Venturini[♣] *

Preliminary draft

Abstract

This paper explores the relationship between innovation and inequality using the lens of the Schumpeterian growth theory. We develop a two-country growth model with trade in intermediate goods and households' heterogeneity in wealth endowment. In the model, wealth inequality generates income inequality, whereas innovation contributes to shape the endogenous distribution of income. We show that a change in the domestic R&D efficiency (productivity) has both positive and negative effects on income inequality in the domestic economy, with an ambiguous overall impact. To assess which effect empirically prevails, we estimate the relationship between between research productivity and income distribution on a sample of 21 OECD countries using historical data from 1920 to 2015, based on long-run (cointegration) regression. We find a positive association between R&D productivity and a large battery of indicators of income inequality. Furthermore, we assess the short-run sensitivity of inequality to an institutional change that facilitated international patenting, *i.e.*, the adhesion to Patent Cooperation Treaty. Based on the local projection analysis, we simulate the effect of this shock on income inequality and compare it against the counter-factual income distribution induced by a random shock or, alternatively, by the entrance to the European Union by some countries of our sample. This analysis confirms that a more uneven income distribution emerges when research productivitity/efficiency increases.

Keywords: Income inequality; R&D productivity; Schumpeterian growth

*[◇] University of Western Australia (AU). [♠] University of Bologna (IT) [♣] University of Perugia (IT) & NIESR (UK). The authors thank Gabriele Ciminelli and Pietro Peretto for his helpful comments.

1 Introduction

With income inequality rising in most developed and developing countries, distributional concerns have moved to the center of the political and economic debate. A number of papers have attempted to explain the underlying driving forces of income inequality, arguing that innovation plays a key role in determining the distribution of income among individuals and factor owners. However, there is no consensus about the distributive effects of innovation and the underlying mechanism. According to the extant literature, technological progress can promote economic growth in ways that would imply more or even less inequality (Akcigit et al., 2017). On the one hand, Aghion et al. (2019a), examining US state-level data, find that more innovation-led growth has increased the proportion of national income accruing to top earners since the early 1970s. On the other hand, Jones and Kim (2018) show theoretically that, if innovations come from new entrants, the associated process of creative destruction would fasten income growth and promote income reallocation among entrepreneurs. As a result, the relationship between innovation and inequality could be negative.

The present paper contributes to this influential body of research by investigating how innovation affects income inequality by means of research productivity (or R&D efficiency), defined as innovative output per unit of effort expended on the innovation process. Earlier studies have paid attention to decreasing returns to R&D, the diminishing technological opportunities lying behind this process and analyzed how all these factors reverberate on economic growth (Madsen, 2008a, Venturini, 2012, Bloom et al., 2020), but have neglected how R&D efficiency shapes the distribution of income. In this work, we document that innovation explains a large portion of cross-country variation in income inequality over the last century showing that a crucial role is played by research productivity.

In order to analyze this issue, we use the lenses of Schumpeterian growth theory and develop a two-country growth model with trade in intermediate goods and households' heterogeneity in wealth endowment. In accordance with the empirical evidence in Piketty (2014, Ch. 7), in our model, wealth inequality generates income inequality. Innovation, in turn, contributes to shape the endogenous distribution of income. In our open-economy setting, economic growth depends on both domestic and foreign technologies. As a result, the income distribution in a country is affected by domestic innovation which responds to changes in R&D productivity at home and, through international trade, by foreign innovation which reacts to changes in foreign research productivity.

Our growth-theoretic analysis suggests that a change in the domestic R&D efficiency has both positive and negative effects on income inequality in the domestic economy. More specifically, we identify three channels through which innovation shapes the distribution of income in the home country. Two channels operate through the positive link between economic growth and domestic innovation. A higher rate of economic growth, driving up the rate of return on assets, increases the share of total income going to the asset-wealthy households. Meanwhile, by affecting both consumption/saving and labor supply choices, a higher rate of economic growth increases labor income, favouring relatively more households with a larger amount of assets. As a result, both channels contribute to rise income inequality. Conversely, the degree of R&D efficiency (productivity) unequivocally reduces income inequality by operating through the process of creative destruction. A higher R&D productivity, by speeding up the arrival rate of innovation, decreases the market value of firms, which in turn makes the distribution of income less unequal. As a result of these opposing effects, we show that a change in the domestic R&D productivity has an overall ambiguous impact on income inequality.

To assess which effect empirically prevails, we bring the theory to the data and estimate the relationship between innovation and inequality on a sample of 21 OECD countries between 1920 and 2015, based on long-run (cointegration) regression. We find a positive association between R&D productivity (efficiency) and a large battery of indicators of income inequality, namely relative factor income, capital share, top income share (at various percentiles) and the Gini index. Our results are found to hold over the time span of one century, in different time intervals, and to be robust to using alternative proxies for research productivity or controlling for several macroeconomic conditions. Not less relevantly, we document that both domestic and foreign research productivity raise inequality and, in line with the model's predictions, this finding holds even when we control for other crucial drivers of the income distribution such as the firms' market power. This corroborates the view that the distributive effect of R&D efficiency (productivity) does not capture more general effects associated with the market structure (firm exits/entries), business dynamics, demand conditions, etc.

Furthermore, we assess the short-run sensitivity of inequality to an institutional change that facilitated international patenting and, hence, the exploitation of innovation's rents, *i.e.*, the adhesion to Patent Cooperation Treaty. Based on the local projection analysis, we simulate the effect of this shock on income inequality and compare it against the counter-factual income distribution induced by a random shock or, alternatively, by the entrance to the European Union by some countries of our sample. This analysis confirms that a more uneven income distribution emerges when innovation output grows more than R&D costs (i.e. research productivitity/efficiency increases), and that the estimated response coefficient is comparable with the long-run impact of research productivity estimated in cointegration regressions.

Our paper contributes to several literatures. First, it relates to the Schumpeterian growth studies investigating how innovation and economic growth impact on income distribution (Jones and Kim, 2018; Aghion et al., 2019a; Akcigit et al., 2017).[1] A few studies adopt a framework with heterogeneity in assets' households similar to ours, studying how the nexus between innovation and inequality is affected

[1] Earlier studies look at the reverse direction of causality, *i.e.* how inequality impacts on economic growth via physical and human capital accumulation (Galor and Zeira, 1993, Aghion and Bolton, 1997, Galor and Moav, 2004 and by changing the demand and supply of R&D (Zweimuller, 2000; Foellmi and Zweimüller, 2006; García-Peñalosa and Wen, 2008).

by patent policy (Chu and Cozzi, 2018;Chu et al., 2021), international trade (Cozzi and Impullitti, 2010), monetary policy (Chu et al., 2019), and arises as the result of a process of endogenous transition from stagnation to growth (Chu and Peretto, 2019).

Another related literature looks at factor income distribution (Piketty and Zucman, 2014, Waldenström, 2021). Peretto and Seater (2013) propose a R&D-driven growth theory of factor-eliminating technical change in which innovation pursued by profit-seeking firms would raise the capital share on national income. O'Mahony et al. (2020) document, however, that investments in R&D are positively related to the labor share, mitigating the downward pressure exerted by physical capital accumulation (Karabarbounis and Neiman, 2014).[2]

The present work is also linked to those studies investigating the creation and sharing of innovation-driven rents at firm-level (Van Reenen, 1996 Kline et al., 2019), and how these distribute across workers by skill type (Aghion et al., 2019b). At the macroeconomic level, the distributive effects of innovation-led rents remain largely un-explored. Aghion et al. (2019c) develop a theory of falling growth and rising rents in which the driving force is the falling organisational costs induced by the innovation in the field of information technology.

Finally, we also relate to the macroeconomic literature on R&D difficulty which posits that innovation would be increasingly costly due to the exhaustion of technological opportunies, explaining why productivity growth is stationary despite R&D is increasing (Jones (1995), Segerstrom, 1998).[3] Evidence corroborating this view can be found for the US in Venturini (2012) and Bloom et al. (2020), and for other major OECD countries in Oh and Takahashi (2020), Boeing and Hünermund (2020), Beneito et al. (2015).

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 through changes in research productivity. Section 4 describes the data. Section 5 describes the econometric model and presents regression results including several robustness checks. Section 6 investigates the short-run response of inequality to the adhesion to Patent Cooperation Treaty.

[2]Since firms can also assimilate innovation embodied in the latest investment goods, an increasing number of works have assessed the macroeconomic impact of automation (and ither disurptive technologies) on the labor share and wage inequality (Graetz and Michaels, 2018 Acemoglu and Restrepo, 2018, Martinez, 2019, Prettner and Strulik, 2020).

[3]Another stream of studies suggests that the increasing R&D difficulty would be the endogenous outcome of the job mismatch between researchers and entreprenerus (Michelacci, 2003). Ngai and Samaniego (2011) design how diminishing technological opportunities, appropriabilty and demand conditions shape cross-industry differences in R&D intensity and TFP growth.

2 Model

The Schumpeterian quality-ladder model is based on Grossman and Helpman (1991) and Aghion and Howitt (1992). We consider a two-country version of the model featuring heterogeneity in households' wealth as in Chu and Cozzi (2018) and Chu et al. (2019) and elastic labor supply. The domestic country is denoted with a superscript d, whereas the foreign country is denoted with a superscript f. Both countries engage in R&D even though one may be more productive than the other in conducting innovation. To save space, we will focus on the domestic economy, recalling that, for each variable and equation of the home country, there exists an analogous expression for the foreign one.

2.1 Households

In the domestic country d, there is a unit continuum of households indexed by $x \in [0,1]$ with identical preferences over consumption and leisure and different levels of asset holdings.[4] Each household x has the following utility function:

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

where $\rho > 0$ is the discount rate and $c_t^d(x)$ is household x's consumption of final good. Each household is endowed with one unit of time to allocate between leisure and work. We denote by $(1 - l_t^d(x))$ the fraction of time devoted to leisure by household x, whereas $\theta > 0$ is the elasticity of instantaneous utility with respect to leisure. Each household earns wage income and maximizes utility under the following asset-accumulation equation:

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

where $a_t^d(x)$ is the real value of financial assets owned by household x, r_t^d is the real interest rate, w_t^d is the real wage rate and $l_t^d(x)$ is the fraction of time devoted to work. Household x's share of financial assets at time 0 is exogenously given by $\phi_{a0}^d(x) \equiv a_0^d(x)/a_0^d$ which follows a general distribution with a mean of zero and standard deviation of σ_a^d.

Solving household x's intratemporal optimization problem yields the fraction of time devoted to work, namely $l_t^d(x) = 1 - \theta c_t^d(x)/w_t^d$. Denoting by $C_t^d \equiv \int_0^1 c_t^d(x)\mathrm{d}x$ aggregate consumption in the domestic country, aggregate labor supply, $L_t^d \equiv \int_0^1 l_t^d(x)\mathrm{d}x$, writes as:

$$L_t^d = 1 - \theta \frac{C_t^d}{w_t^d}. \tag{2}$$

Finally, from standard dynamic optimization, the Euler equation is given by:

$$\frac{\dot{c}_t^d(x)}{c_t^d(x)} = \frac{\dot{C}_t^d}{C_t^d} = r_t^d - \rho, \tag{3}$$

[4] In our model, households have homothetic preferences so that the income distribution has no effect on the aggregate economy. As a result, changes in income inequality do not affect economic growth.

which shows that the growth rate of consumption is the same across households.

2.2 Final good

In the domestic economy, a homogeneous good, Y_t^d, is produced by perfectly competitive firms that aggregate two types of final goods using a Cobb-Douglas aggregator:

$$Y_t^d = \frac{(Y_t^{dd})^{\beta}(Y_t^{df})^{1-\beta}}{\beta^{\beta}(1-\beta)^{1-\beta}}, \tag{4}$$

where Y_t^{dd} and Y_t^{df} denote final goods produced with domestic and foreign intermediate inputs, respectively. The parameter $\beta \in (0,1]$ determines the share of domestic production consumed domestically. From profit maximization, the conditional demand functions for Y^{dd} and Y^{df} are:

$$Y_t^{dd} = \beta \frac{Y_t^d}{P_{yt}^{dd}}, \quad Y_t^{df} = (1-\beta)\frac{Y_t^d}{P_{yt}^{df}}, \tag{5}$$

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

Competitive firms in country h produce final goods using a standard Cobb-Douglas aggregator over a unit continuum of domestic and foreign intermediate inputs, $X_t^{dd}(i)$ and $X_t^{df}(i)$, for $i \in [0,1]$, 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 inputs $X_t^{dd}(i)$ and $X_t^{df}(j)$, namely:

$$X_t^{dd}(i) = \frac{P_{yt}^{dd}}{p_{xt}^{dd}(i)} Y_t^{dd}, \quad X_t^{df}(j) = \frac{P_{yt}^{df}}{p_{xt}^{df}(j)} Y_t^{df}, \tag{6}$$

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 the standard price indices for Y_t^{dd} and Y_t^{df} amount, respectively, to $P_{yt}^{dd} \equiv \exp\left(\int_0^1 \ln p_{yt}^{dd}(i)\mathrm{d}i\right)$ and $P_{yt}^{df} \equiv \exp\left(\int_0^1 \ln p_{yt}^{df}(j)\mathrm{d}j\right)$.

2.3 Intermediate inputs

Intermediate inputs are freely traded and labor is immobile across the two countries. In the domestic economy, there is a unit continuum of industries indexed by $i \in [0,1]$. In each industry i, an industry leader employ domestic workers to produce the intermediate inputs for domestic and foreign sales, $X_t^{dd}(i)$ and $X_t^{fd}(i)$:

$$X_t^{dd}(i) = (z^d)^{N_t^d(i)} L_{xt}^{dd}(i), \quad X_t^{fd}(i) = (z^d)^{N_t^d(i)} L_{xt}^{fd}(i), \tag{7}$$

where $z^d > 1$ is the step size of innovation, $N_t^d(i)$ is the number of quality improvements occurred in industry i and $L_{xt}^{dd}(i)$ and $L_{xt}^{fd}(i)$ denote, respectively, the amount of labor employed in the production of intermediate inputs $X_t^{dd}(i)$ and $X_t^{fd}(i)$. Thus, the total number of workers employed in industry i amounts to $L_{xt}^d(i) = L_{xt}^{dd}(i) + L_{xt}^{fd}(i)$.

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

$$p_{xt}^{dd}(i) = p_{xt}^{fd}(i) = \psi \frac{w_t^d}{(z^d)^{N_t^d(i)}}, \tag{8}$$

and the total amount of monopolistic profits earned by the industry i's leader writes as:

$$\pi_t^d(i) = \pi_t^{dd}(i) + \pi_t^{fd}(i) = \left(\frac{\psi - 1}{\psi}\right)\left[p_{xt}^{dd}(i)X_t^{dd}(i) + p_{xt}^{fd}(i)X_t^{fd}(i)\right] = \left(\frac{\psi - 1}{\psi}\right)(P_{yt}^{dd}Y_t^{dd} + P_{yt}^{fd}Y_t^{fd}), \tag{9}$$

where the last equality of this equation follows from Eq. (6). Finally, wage income paid to industry i's workers in the domestic country is:

$$w_t^d L_{xt}^d(i) = w_t^d L_{xt}^{dd}(i) + w_t^d L_{xt}^{fd}(i) = \frac{p_{xt}^{dd}(i)X_t^{dd}(i) + p_{xt}^{fd}(i)X_t^{fd}(i)}{\psi} = \frac{P_{yt}^{dd}Y_t^{dd} + P_{yt}^{fd}Y_t^{fd}}{\psi}, \tag{10}$$

which shows that workers receive the same income in all industries.

2.4 Innovations and R&D

Let us denote the expected value of an innovation in industry i of the domestic country as $v_t^d(i)$. According to Eq. (9), monopolistic profits are the same across industries, that is $\pi_t^d(i) = \pi_t^d$ for all $i \in [0, 1]$. Hence, in a symmetric equilibrium, the value of inventions is the same in all industries, namely $v_t^d(i) = v_t^d$ for all $i \in [0, 1]$. Following Dinopoulos and Segerstrom (2010), we assume home bias in asset ownership so that the shares of monopolistic firms created by innovation in a country are owned by domestic households.[5] Given this assumption, the market value of an innovation in the home country is equal to the total value of financial assets owned by domestic households, namely $a_t^d = v_t^d$. The familiar no-arbitrage condition for v_t^d equates the real interest rate, r_t^d, to the asset return per unit of financial assets, that is:

$$r_t^d = \frac{\pi_t^d + \dot{v}_t^d - \lambda_t^d v_t^d}{v_t^d}, \tag{11}$$

which shows that the asset return is the sum of monopolistic profits, π_t^d, capital gain, $\dot{v}_t^d$, and expected capital loss, $\lambda_t^d v_t^d$, due to creative destruction, where λ_t^d denotes the aggregate-level Poisson arrival rate of innovation in the home country.

[5] Using OECD data, Feldstein and Horioka (1980) show that there exists a close relationship between domestic investment and saving. French and Poterba (1991) and Tesar and Werner (1995) provide further evidence of a home country bias in asset portfolios.

In each country, there is a unit continuum of R&D entrepreneurs indexed by $\iota \in [0,1]$ that devote $R_t^d(\iota)$ units of final good to R&D activities. The expected profits for the entrepreneur ι is equal to $\Pi_t^d(\iota) = v_t^d \lambda_t^d(\iota) - R_t^d(\iota)$, where $\lambda_t^d(\iota)$ is the firm-level arrival rate of innovation which we assume equal to:

$$\lambda_t^d(\iota) = \vartheta^d \frac{R_t^d(\iota)}{D_t^d \Omega_t^d}. \tag{12}$$

In the previous equation, $\vartheta^d > 0$ denotes the domestic R&D productivity (which may differ from the foreign one), $D_t^d \equiv (Z_t^d)^\beta (Z_t^f)^{1-\beta}$ is the aggregate index of R&D difficulty which is a combination of the levels of technology in the two economies and $\Omega_t^d \equiv (L_t^d)^\beta (L_t^f)^{1-\beta}$ is a growth trend depending on the amount of labor employed in each country. According to Eq. (12), the probability of the next successful innovation is increasing in R&D spending, $R_t^d(\iota)$, and decreasing in R&D difficulty, D_t^d, which captures the idea that research on more advanced products becomes more difficult due to technological complexity (Segerstrom, 1998, Venturini, 2012). As a result, one unit of R&D expenditure is proportionally less effective when applied to a more sophisticated product. Finally, to eliminate the scale effect on long-run growth, we assume that the arrival rate of innovation depends on R&D expenditure per unit of labor employed in the two economies.

Free entry in the R&D sector implies zero expected profits so that:

$$v_t^d = \frac{D_t^d \Omega_t^d}{\vartheta^d}. \tag{13}$$

Finally, using Eq. (12) and aggregating over entrepreneurs yield the arrival rate of innovation in the home country:

$$\lambda_t^d = \int_0^1 \lambda_t^d(\iota) \mathrm{d}\iota = \vartheta^d \frac{R_t^d}{D_t^d \Omega_t^d}. \tag{14}$$

3 Solving the model

In this section, we study the equilibrium of the model, focusing on the domestic country.[6] We first show that the aggregate economy always jumps to a unique and stable balanced-growth path along which the interest rate and the arrival rate of innovation remain constant, whereas all the other aggregate variables grow at a constant (equal) rate. We then analyze the effects of R&D efficiency on income inequality.

3.1 Aggregate economy

Substituting X_t^{dd} from (7) into Y_t^{dd}, we easily 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:

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

[6] We relegate the definition of the equilibrium to Appendix A.1.

where the second equality derives from the law of large numbers. Differentiating the log of Z_t^d with respect to t gives the growth rate of aggregate technology in the domestic economy, that is:

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

Similarly, substituting X_t^{df} into Y^{df} yields $Y_t^{df} = Z_t^f L_{xt}^{df}$ where aggregate technology in the foreign country is defined as $Z_t^f \equiv \exp\left(\int_0^1 N_t^f(j)\mathrm{d}j \ln z^f\right) = \exp\left(\int_0^t \lambda_s^d \mathrm{d}s \ln z^f\right)$. Differentiating the log of Z_t^f with respect to t yields the growth rate of aggregate technology in the foreign country, namely:

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

In Appendix A.3 we study the dynamics of the model and show that the aggregate economy jumps to a unique and stable balanced growth path (BGP) along which the arrival rates of innovation, λ_t^d and λ_t^f, take respectively the following stationary values, $\lambda^d = \vartheta^d(\psi - 1)/\psi - \rho$ and $\lambda^f = \vartheta^f(\psi - 1)/\psi - \rho$. Thus, both the growth rates of technology, $\dot{Z}_t^d/Z_t^d$ and $\dot{Z}_t^f/Z_t^f$, also jump to their steady-state values.

Moreover, the aggregate variables $\{a_t^d, v_t^d, Y_t^d, \pi_t^d, C_t^d, w_t^d\}$ grow at the same rate as the index of R&D difficulty, D_t^d, namely:

$$g^d \equiv \frac{\dot{D}_t^d}{D_t^d} = \beta\lambda^d \ln z^d + (1-\beta)\lambda^f \ln z^f = \beta\left[\vartheta^d\frac{(\psi-1)}{\psi} - \rho\right]\ln z^d + (1-\beta)\left[\vartheta^f\frac{(\psi-1)}{\psi} - \rho\right]\ln z^f, \quad (15)$$

which represents the steady-state growth rate of the domestic economy. Using the Euler equation (3), the domestic interest rate amounts to $r_t^d = r^d = g^d + \rho$.

As for the distribution of assets, in Appendix A.4, we show that the wealth distribution in both economies is stationary and determined by its initial distribution that is exogenously given at time 0.

3.2 Income inequality

We now derive the distribution of income and explore how domestic and foreign R&D efficiencies affect income inequality domestically. Income earned by household x is equal to $I_t^d(x) = r_t^d a_t^d(x) + w_t^d l_t^d(x)$, whereas the aggregate level of income amounts to $I_t^d = r_t^d a_t^d + w_t^d L_t^d$. Let $\phi_{It}^d(x) \equiv I_t^d(x)/I_t^d$ denote the share of income received by household x. In Appendix A.5, we show that $\phi_{It}^d(x)$ can be expressed as:

$$\phi_{It}^d(x) = \frac{(r_t^d + \theta g^d)a_t^d\phi_{a0}^d(x) + w_t^d}{(r_t^d + \theta g^d)a_t^d + w_t^d}.$$

This equation implies that the distribution of income share at time t has a mean of one and a standard deviation equal to:

$$\sigma_{It}^d = \sqrt{\int_0^1 [\phi_{It}^d(x) - 1]^2 \mathrm{d}x} = \frac{(r_t^d + \theta g^d)a_t^d/w_t^d}{(r_t^d + \theta g^d)a_t^d/w_t^d + 1}\sigma_a^d, \quad (16)$$

which we take as a measure of income inequality.

A change in the domestic R&D productivity, ϑ^d, has both positive and negative effects on income inequality. More specifically, we identify three channels through which innovation shapes the distribution of income. Two channels operate through the innovation-economic growth link and contribute to rise income inequality (income-growth effect): increases in the domestic R&D productivity favour the process of innovation which, in turn, promotes economic growth in the domestic economy, as it is shown by Eq. (15). First, a higher rate of economic growth, g^d, drives up $r_t^d = g^d + \rho$ in Eq. (16). The resulting higher return on assets increases the difference between the share of income earned by the richest and the poorest in the country, leading to an increase in income inequality. Second, economic growth impacts on income inequality by affecting the labor-leisure choice of the households. This effect is captured by the term θg^d in Eq. (16). As shown in Appendix A.5, household x's consumption and income are respectively equal to:

$$c_t^d(x) = \frac{a_t^d(x)(r_t^d - g^d) + w_t^d}{\theta + 1}, \qquad I_t^d(x) = \frac{(r_t^d + \theta g^d)a_t^d(x) + w_t^d}{\theta + 1},$$

which show that, holding the interest rate, r_t^d, constant, a higher growth rate, g^d, reduces the household's consumption, $c_t^d(x)$, by reducing its level of saving, $a_t^d(x)g^d$. Under elastic labor supply, this lower level of consumption decreases the household's leisure which, in turn, rises its labor income. Since this effect is stronger for households owning a larger amount of assets, this channel also rises income inequality in the home economy. Finally, the third channel is driven by the process of creative destruction and operates through the asset-wage ratio, a_t^d/w_t^d, in Eq. (16). A higher domestic R&D productivity, ϑ^d, by speeding up the arrival rate of innovation, decreases the market value of firms, which in turn lowers the asset-wage ratio in the domestic economy, namely:

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

This effect tends to make the distribution of income less unequal (asset-wage effect). As a result of these opposing effects, a change in the domestic R&D efficiency has an overall ambiguous impact on income inequality in the home country.

At this point of the analysis, it also becomes evident that an increase in the foreign R&D efficiency, ϑ^f, has an unambiguous positive impact on income inequality in the domestic economy. Due to cross-country spillovers arising from trade in intermediate goods, improvements in foreign R&D productivity enhance economic growth in the home country, as shown in Eq. (15). The resulting higher growth rate, g^d, rises income inequality domestically.

4 Data description

We assess the relation between research productivity and income inequality using historical macroeconomic data for 21 OECD countries between 1920 to 2015. We measure income inequality with the factor (or capital-to-labor) income ratio and, in turn, with other standard measures such as the share of capital income on GDP, the share of top earners at various percentiles of income distribution and the Gini index. Capital and labor income series are updates of the data assembled in Madsen et al. (2018). Top income shares and the Gini index series are taken from (and extend) data in Islam and Madsen (2015).

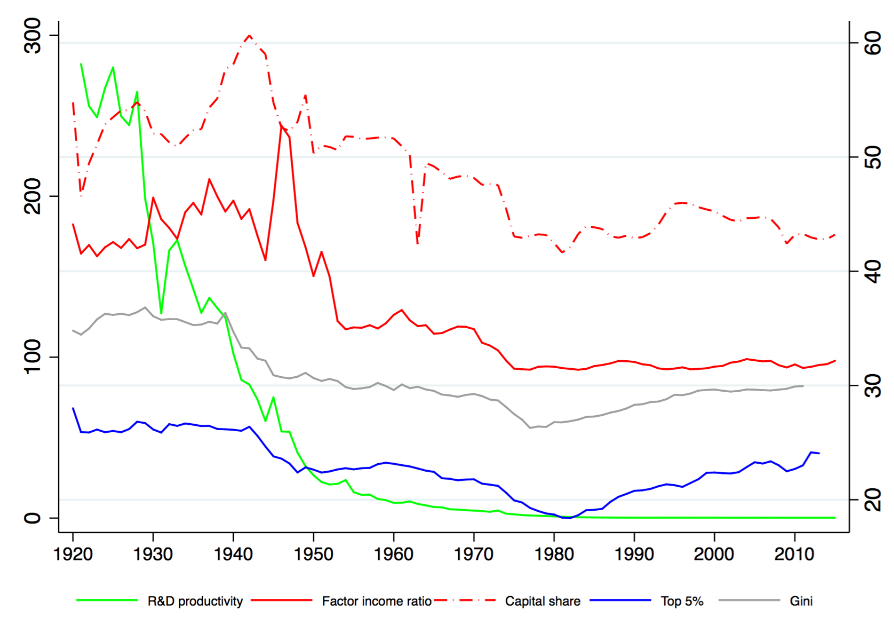
Our measure of research productivity is defined as the number of patent counts per adjusted research input. Historical patent statistics derive from World Intellectual Property Organisation, WIPO (Madsen, 2008b). Research input is defined as real expenses in R&D deflated, in accordance with the model, by the product between R&D difficulty, as proxied by total factor productivity (TFP), and population (Madsen, 2008a). In our economy-open regressions, the index of R&D difficulty is the sum of a domestic and a foreign component, with the latter being proxied by a geographic proximity-weighted average of the product between TFP and population. Historical R&D data come from Madsen et al. (2021). TFP is derived from a Cobb-Douglas output technology using annual series on real GDP, capital stock and employees (and their factor income shares).

In robustness checks, we take advantage of the latest advances in historical patenting research and make use of the Comprehensive Universe of U.S. Patents dataset (CUSP, Berkes, 2018). This provides information on USPTO applications since 1836, such as (disambiguated) assignee's names and country of origin, patents' technological classes, cites made and received. These data are used to build measures of: (i) quality-adjusted patents, where each application is weighted by the number of forward cites received or by a generality/originality index;[7] (ii) product quality improvement, proxied by the forward citations' ratio between the two most cited patents in each technological class; and (iii) the rate of technology market exit, defined by the number of patent assignees leaving the technology market over total number of innovators (respectively taken at time t and $t-1$).

In the sensitivity analysis, in alternative to TFP, we proxy the index of research difficulty with two indicators commonly used in the Schumpeterian growth literature, namely the amount of trademarks (source: WIPO) and product quality improvement (see above). The former variable would capture the crowding-out effect of product proliferation on the expanding research expenditure (fully endogenous growth; Madsen, 2008a). The latter variable would capture the fact that technological opportunities run

[7]The index of patent originality (generality) is computed as one minus the adjusted Herfindahl-Hirschman Index (HHI) of concentration of backward (forward) citations based on the 4-digit international patent classes (IPC) of the citing (cited) patent (Hall et al., 2001). To avoid distortion associated with the truncation in the time window to be cited for the most recent applications, forward cites are always scaled on the average number of annual cites at country level.

Figure 1: **Inequality and R&D productivity, 1920-2015 (unweighted means)**

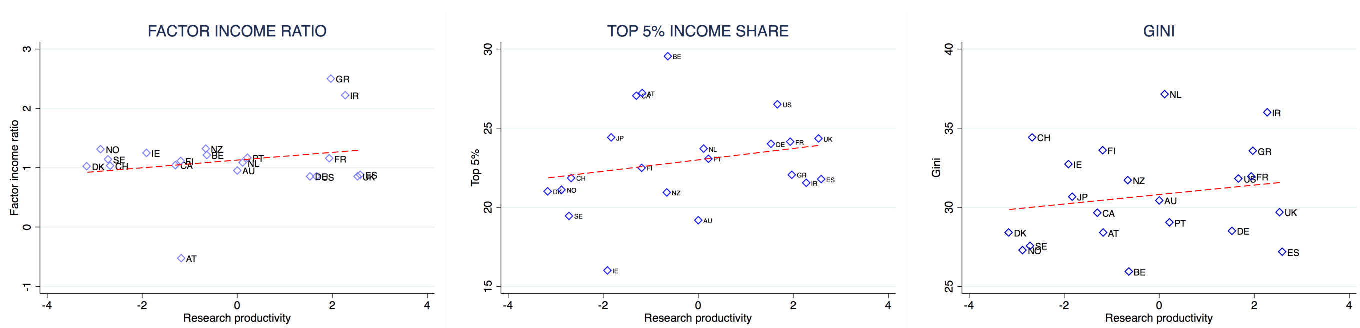


Notes: Research productivity and factor income ratio as indexed on the left-hand axis. Top income shares, the Gini index and the capital share on income are indexed on the right-hand side axis.

out and R&D is increasingly difficult when new products are brought onto the market (semi-endogenous growth; Venturini, 2012).

Figure 1 illustrates the dynamics over time of our main variables, taken as un-weighted cross-country average. The graph shows that co-movements between research productivity and income inequality measures run for most of our time interval. Figure 2 plots the bivariate correlation between research productivity and (a sub-set of) inequality indicators, obtained using country-level means. There is a positive association between these variables that looks more pronounced for the top 5% income share.

Figure 2: **Correlation between inequality and R&D productivity**



Notes: Bivariate correlation between log of research productivity and income inequality based on country-means.

5 Empirical results: The long run

Our theoretical framework shows that domestic research productivity would have opposing effects on income inequality and the overall impact is ambiguous In this second part of the paper, we seek to address this puzzle empirically. As a first step, in this section, we estimate a long-run, structural model relating research productivity to a set of income inequality measures, based on cointegration regression. As a second step, (Section 6), we assess the short-run responsiveness of income inequality to exogenous shocks on research productivity, captured by a change in the institutional setting ruling international patent competition.

To identify the long-run effect of our variable of interest, we estimate a log-linear specification, shaped as follows:

$$\ln \sigma_{It} = \alpha_{i0} + \alpha_1 \ln \eta_{it} + \epsilon_{it} \tag{17}$$

where i denote countries, t years from 1920 to 2015. Based on the model's predictions, α_1 would identify the net effect of domestic research productivity, combining both the asset-wage effect (negative) and the income-growth effect (positive). A negative value for α_1 would indicate that the process of creative destruction —which reduces the discounted value of incumbents' profits and households' assets — prevails against the increase in asset holders' income associated with the surge in the interest rate and the labor income induced by a faster income growth rate. Instead, a positive value for α_1 would suggest the opposite.

Equation (17) is reformulated as an error correction mechanism (ECM) and estimated assuming homogeneous parameters and including common correlation effects (CCEs) to capture country-specific effects of un-observable shocks.[8] The ECM regression yields long-run (cointegration) estimates of the relation under investigation, which are asymptotically robust to reverse causality, measurement errors, omitted variables' issues affecting static procedures of regressions.[9]

5.1 Baseline results

Table 1 illustrates the effect of domestic research productivity on our battery of income inequality indicators. The reported values consist in the long-run (cointegration) parameters, and the associated standard errors are robust to serial correlation and heteroskedasticity (Newey-West standard errors). Panel A considers our main proxy for research productivity, defined as the ratio between patent counts and adjusted R&D expenses. Panel B estimates the effect on income inequality of innovation output

[8] The ECM specification is estimated using a five-year lag order both for first-differenced (short-run) regressors and CCE terms.

[9] Juodis et al. (2020) demonstrate that the pooled CCE estimator used in the present study is generally consistent even when unobservable factors are correlated with regressors but, in this case, asymptotic normality remains dubious when the true number of factors exceeds that of the explanatory variables.

(patenting output) and innovation input (research expenses) separately.

Table 1: **Baseline estimates** (1920-2015)

	(1) FACTOR INCOME RATIO	(2) CAPITAL SHARE	(3) TOP 0.1%	(4) TOP 1%	(5) TOP 5%	(6) TOP 10%	(7) GINI
				PANEL A			
Research productivity	0.182***	0.071***	0.086***	0.054***	0.039***	0.014***	0.011***
	(0.006)	(0.002)	(0.008)	(0.005)	(0.003)	(0.003)	(0.003)
Observations	1,560	1,560	1,710	1,710	1,710	1,710	1,668
R-squared	0.937	0.913	0.880	0.908	0.881	0.895	0.881
				PANEL B			
Patent counts	0.284***	0.114***	0.214***	0.077***	0.059***	0.031***	0.031***
	(0.012)	(0.005)	(0.015)	(0.012)	(0.008)	(0.007)	(0.004)
Adjusted R&D costs	-0.131***	-0.027***	-0.089***	-0.013	-0.069***	-0.036***	0.001
	(0.007)	(0.003)	(0.009)	(0.009)	(0.004)	(0.004)	(0.003)
Observations	1,575	1,575	1,730	1,730	1,730	1,730	1,688
R-squared	0.917	0.895	0.815	0.736	0.845	0.848	0.856

Notes: Long-run estimates derived from a panel Error Correction Mechanism specification. All variables are expressed in logs. Estimates include country-specific fixed effects and common correlated effects (CCE). The number of time lags for first-difference regressors and CCEs is set to 5. Newey-West standard errors in parentheses. Research productivity is measured as the ratio between patent counts and adjusted R&D expenses. Real R&D expenses are discounted by a difficulty index defined as the product between TFP and population. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Estimates in the upper section of the table unequivocally indicates that domestic research productivity is positively and significantly associated with income inequality, irrespective of how the latter is measured. The larger elasticity is found for the factor income ratio (0.182), followed by the capital share and top 0.1% income share. The impact of research productivity reduces as long as we expand the share of income top earners, from 0.086 for top 0.1% to 0.014 for top 10% income share. The impact estimated on the Gini index falls close to the effect found on top 10% income inequality (0.011).

Lower-panel estimates indicate that a larger innovation output, measured by the number of patents counts, raises income inequality, with an elasticity ranging from 0.28 for factor income share to 0.031 for the Gini index and the top 10% income share. Conversely, a larger R&D effort is usually associated with a lower income inequality. This effect is significant in all specifications expect those using the Gini index and the top 1% income share as dependent variable. The impact estimated for patenting on inequality effects is consistent with the evidence provided by Aghion et al. (2019a) for the US states, and Bengtsson et al. (2020) in a cross-country study on the drivers of the capital share on income. The impact we identify for R&D expenditure on the capital share is consistent, for direction and magnitude, with the effect estimated for such investment types by O'Mahony et al. (2020) on the labor share.

5.2 The inequality impact of innovation across time intervals

Table 2 inspects how the inequality effect of research efficiency has changed over the last century, shedding light on the latest decades when the upward trend in inequality has become steeper (mainly in 1980-2015). In this exercise, we also account for the fact that the success of innovation has become increasingly dependent on complementary intangible assets, such as software. For this reason, in the last column of the table we estimate our empirical model for the latter sub-interval using investment data on Intellectual Property and Products, IPP (see Koh et al., 2020 and Madsen et al., 2021). To save space, estimates in Table 2 are limited to a sub-set of income inequality indicators; the reader is referred to the Appendix B for a complete set of results.

As the table shows, the detrimental effect of research productivity on the factor income ratio is stable from 1950 onwards; the large coefficient of the explanatory variable from 1920 is likely to reflect the steep downward co-movements in this measure of inequality and R&D efficienty in the pre-WWII period (see Figure 1). Conversely, R&D efficiency has a considerably larger coefficient from the 1980s in the regressions using top 5% income share and the Gini index. The latter set of estimates do not change much if we approximate research effort with R&D or IPP investment expenditure.

5.3 Robustness to measurement issues

The analysis proceeds by assessing the sensitivity of estimates to some measurement issues that, for simplicity, we limit to top 5% income share (Table 3).[10] We consider different measures of innovative output (patent) in cols. (2)-(5), and alternative measures of adjusted research input in cols. (6)-(9).

As a first step, we replicate our baseline model in col. (1) using patents taken from the CUSP dataset (col. (2)). The number of applications at the USPTO is smaller than in the WIPO dataset, as the latter collects applications by residents in each own jurisdiction. However, reasonably, only the most technologically advanced innovations, or those with greater commercial value, are applied at the USPTO due to the cost and the length of the filing procedure, implying that the CUSP data might yield a different pattern of effects for the R&D efficiency. Nonetheless, estimates in col. (2) are largely comparable to those in col. (1) based on WIPO data. Next, we build quality-adjusted measures of patenting output by multiplying each application with a quality measure, namely forward cites (col. (3)), the originality index (col. (4)), and the generality index (col. (5)). Taken as a whole, all these

[10]The full set of estimates is shown in Appendix B.

Table 2: **The inequality impact of innovation across time intervals**

	(1)	(2)	(3)	(4)
	1920-2015	1950-2015	1980-2015	1980-2015
		R&D		IPP
		FACTOR INCOME RATIO		
Research productivity	0.182***	0.052***	0.053***	0.025**
	(0.006)	(0.009)	(0.009)	(0.010)
Obs.	1,560	1,214	660	660
R-squared	0.937	0.850	0.861	0.877
		TOP 5% INCOME SHARE		
Research productivity	0.039***	0.013**	0.053***	0.068***
	(0.003)	(0.005)	(0.009)	(0.011)
Obs.	1,710	1,250	651	651
R-squared	0.881	0.816	0.745	0.737
		GINI		
Research productivity	0.011***	0.006	0.032***	0.036***
	(0.003)	(0.004)	(0.006)	(0.006)
Obs,.	1,668	1,208	609	609
R-squared	0.881	0.803	0.796	0.825

Notes: Long-run estimates derived from a panel Error Correction Mechanism specification. All variables are expressed in logs. Estimates include country-specific fixed effects and common correlated effects (CCE). The number of time lags for first-difference regressors and CCEs is set to 5. Newey-West standard errors in parantheses. Research productivity is measured as the ratio between patent counts and adjusted R&D expenses in cols. (1)-(3), and between patent counts and IPP expenditure in col. (4). Real R&D (or IPP) expenses are discounted by a difficulty index defined as the product between TFP and population. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

estimates indicate that a rising research productivity is detrimental for income distribution; admittedly, the long-run coefficient of our key explanatory variable is lower using the originality index as patent weighting factor.

As a second step, we use alternative measures of adjusted research input and discount real R&D expenses with TFP only (col. 6), the number of trademarks (col. 7), the index of product quality improvement (col. 8) or assume a time-invariant research difficulty (col. 9). In all these cases, our baseline estimates are confirmed.

Table 3: **Robustness estimates: measurement issues** (1920-2015)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	TOP 5% INCOME SHARE								
Research productivity	0.039***	0.033***	0.029***	0.004**	0.037***	0.038***	0.016***	0.026***	0.024***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)
Obs.	1,710	1,722	1,722	1,722	1,722	1,710	1,699	1,710	1,710
R-squared	0.881	0.912	0.903	0.896	0.902	0.881	0.883	0.886	0.878
Patent data source	WIPO	USPTO	USPTO	USPTO	USPTO	WIPO	WIPO	WIPO	WIPO
Patent indicator	Counts	Counts	Fwc cites × counts	Originality × counts	Generality × counts	Counts	Counts	Counts	Counts
R&D discounting factor	TFP × POP	TFP × POP	TFP × POP	TFP × POP	TFP × POP	TFP	Trademark	Quality jump	None

Notes: Long-run estimates derived from a panel Error Correction Mechanism specification. All variables are expressed in logs. Estimates include country-specific fixed effects and common correlated effects (CCE). The number of time lags for first-difference regressors and CCEs is set to 5. Newey-West standard errors in parantheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.4 Robustness to omitted variables

In Table 4, we consider a set of possible observable confounding factors. In col. (2), we include the unemployment rate to capture structural differences across countries in the functioning of the labor market, in the ability to create job opportunities and distribute income. In col. (3), we control for the ratio between total tax revenues and GDP, used as a proxy for the fiscal burden over the economy. Although this variable is admittedly endogenous to inequality —as countries with a more uneven income distribution are more likely to arrange redistribution policies —here it is used to capture differences in tax collection, a factor that may be correlated with public engagement in R&D. Population growth is used in col. (4) as control to filter out demographic differences in the cohorts of youths entering the working-age population. Educational investment is lower in countries with higher rates of fertility and population growth, implying lower income wage in the long run.

Globalisation is another factor usually argued to widen income inequality, as it promotes substitution between domestic and foreign inputs (or productive tasks). On this basis, we include into the regression a measure of import penetration defined as the value of imports as a share of GDP (col. (5)). The inflation rate is controlled for as this factor may be correlated both with inequality and innovation (col. (6)). Inflation is indeed regressive as reducing individuals' purchasing power at the lower tail of income distribution, raising thus inequality. However, inflation may adversely affect the measured innovative

Table 4: **Estimates with controls** (1920-2015)

	(1)	(2) Unemployment rate	(3) Tax revenues/ GDP	(4) Population growth	(5) Import penetration	(6) Inflation rate	(7) Labor productivity	(8) Tobin's *q*	(9) Bank credit/ GDP	(10) Tertiary education
						TOP 5% INCOME SHARE				
Research productivity	0.054***	0.033***	0.048***	0.089***	0.077***	0.096***	0.089***	0.057***	0.029***	0.078***
	(0.005)	(0.007)	(0.008)	(0.007)	(0.005)	(0.006)	(0.007)	(0.005)	(0.006)	(0.006)
Control		0.001	-0.131***	0.027***	0.114***	-0.006***	-0.270***	0.004	0.132***	-0.198*
		(0.006)	(0.011)	(0.009)	(0.015)	(0.001)	(0.035)	(0.010)	(0.010)	(0.104)
Obs.	1,690	1,690	1,710	1,710	1,710	1,710	1,710	1,710	1,710	1,710
R-squared	0.908	0.832	0.855	0.846	0.876	0.859	0.825	0.895	0.852	0.886

Notes: Long-run estimates derived from a panel Error Correction Mechanism specification. All variables are expressed in logs. Estimates include country-specific fixed effects and common correlated effects (CCE). The number of time lags for first-difference regressors and CCEs is set to 5. Newey-West standard errors in parantheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

output as in periods of high uncertainty a large share of research projects is doomed to fail. In col. (7), average labor productivity is used to filter out structural differences in production technologies that, erronously, may be confused with the sharing of innovation rents. In cols. (8) and (9), we include two financial controls. Tobin's q is used as the coefficient of research productivity may collect the effect of speculative bubbles in the stock market materialising in periods of rapid technological change as during the Nasdaq boom of the late 1990s (col. (8)). The share of bank credit to GDP serves instead to control for the financial development, as this factor may expand the asset income, along with enabling innovation. Finally, the share of population with tertiary education is controlled for in col. (10), as human capital is the ultimate source of a country's ability to generate new ideas, and hence its effects may be mis-measured with that of research productivity. However, as a more general effect, education promotes social mobility, improves working (wage) conditions and reduces income inequality.

All control variables are significant and with the expected sign, but their inclusion does not alter the effect estimated for research productivity on top 5% income inequality. With respect to this pattern, it makes exception only the impact estimated for the unemployment rate and Tobin's q, which turn out to be insignificant.[11]

[11] The full set of estimates in Appendix B illustrates that, among control variable, the ratio of tax revenues to GDP is the covariate with most robust effect across specifications.

5.5 The inequality impact of innovation in open economy

In this section, we take the model's predictions more rigorously and estimate an open-economy framework (see Eq. 12). According to our theoretical setting, domestic research productivity should depend on the difficulty of conducting research at home and abroad, as well as the level of domestic and foreign population; consistently, foreign R&D efficiency should raise an uneven distribution of income. Not less relevantly, income inequality should rise with product quality improvement as this would determine the monopolistic power of the leader on the domestic market.

To match these preditions, in Table 5 we employ a measure of domestic R&D efficiency in which research expenses are discounted by domestic and foreign levels of productivity and population (col. (2)). Next, we consider as explanatory variables foreign research productivity and the state-of-the-art product quality (col. (3)). However, in alternative to the latter variable, in col. (4), we consider the exit rate from the technology market as a proxy for the monopolistic power.

This set of estimates indicates that our economy-open theoretical setting is consistent with international data, and that domestic and foreign research productivity work similarly, having both a positive effect on income inequality. However, the impact of foreign R&D efficiency has to be taken with caution, being the coefficient of this explanatory variable much less stable across specifications. This finding may be explained with the nature of foreign research productivity, which is a built as a proximity-weighted average of national indicators, and this might create an overlap between the effect of this regressor and CCE terms. In line with expectations, both product quality improvement and the exit rate are found to be positively and significantly related to top income inequality. The coefficient size of the exit rate is much larger, probably as this variable captures broader set of factors impacting on income distribution, such as the market structure, demand conditions, etc.

6 Response of inequality to innovation shocks: The short run

As a last assessment, we study the short-run sensitivity of inequality to innovation, by simulating the response of top 5% income share to a shock on research productivity based on the local projections (LP) analysis (Jordá, 2005). We use the estimated response coefficient to infer an elasticity thae we compare with the long-run coefficient yielded by the (ECM) regressions.

As a shock on research productivity, we consider the change in the institutional setting governing international patent competition and use the year of a country's adhesion to the Patent Cooperation Treaty (PCT) as event. This follows, among others, Giorcelli and Moser (2020) who find that the introduction of copyright in Italy in the 1800s triggered the development of artistic creations. The PCT is ruled out by the World Intellectual Property Organization and disciplines patenting activities on a global scale, permitting inventors to extend the legal protection over the innovation from the home country to other legislations in a preferential way. Whether patenting has become easier due to a

Table 5: **Open-economy estimates**

	(1)	(2)	(3)	(4)
		TOP 5% INCOME SHARE		
Domestic research productivity	0.039***	0.044***	0.039***	0.012***
	(0.003)	(0.003)	(0.004)	(0.004)
Domestic quality improvement			0.009***	
			(0.002)	
Domestic exit rate				0.042***
				(0.013)
Foreign research productivity		0.018**	0.146***	0.023***
		(0.007)	(0.016)	(0.008)
Open economy	No	Yes	Yes	Yes
Obs.	1,710	1,710	1,605	1,710
R-squared	0.881	0.880	0.859	0.841

Notes: Long-run estimates derived from a panel Error Correction Mechanism specification. All variables are expressed in logs. Estimates include country-specific fixed effects and common correlated effects (CCE). The number of time lags for first-difference regressors and CCEs is set to 5. Newey-West standard errors in parantheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

modification in the IPRs setting, inequality should change some years after the event as a response to a greater facility to exploit the rents associated with innovation.

The LP approach amounts to run a set of linear regressions of future realizations of income inequality on the current values of a set of covariates. Following Romer and Romer (2017) and Ciminelli et al. (2020), we consider the following LP specification:

$$\begin{aligned} \sigma_{I,it+k} &= \alpha_{0i} + \alpha_t + \alpha_{1k} \cdot E_{it} + \alpha_2 \cdot X_{it} + \sum_{h=1}^{k} (\alpha_3 E_{it+h} + \alpha_4 X_{it+h}) \\ &+ \sum_{l=1}^{5} (\alpha_5 \sigma_{I,it-l} + \alpha_6 E_{it-l} + \alpha_7 X_{I,it-l}) + \varepsilon_{it}. \end{aligned} \tag{18}$$

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). As control, we use the ratio of tax revenues to GDP (X), as the impact of this variable is found above to be particularly stable across specifications (see Table B4 in the Online Appendix). Our empirical model also accounts for by forward effects of the event and control variables, as well as the lagged impact of regressors and the dependent variable (up to five-year lags). α_{0i}'s and α_t's denote, respectively, country and year fixed effects, while ε_{it}'s are normal disturbances. Equation (18) is estimated with the FE-OLS estimator using Eicker-Huber-White heteroskedasticity-robust standard errors, which are found to be robust to serial correlation in lag-augmented LP regressions with persistent series (Montiel Olea and Plagborg-Møller, 2020).

Figure 3 illustrates the response function of the top 5% income share, plotting the single-year coefficients α_{1k} estimated over a 5-year interval (and related 90 and 95% confidence intervals).[12] The reported value corresponds to the absolute change in the inequality indicator. The event regression on the PCT entrance is run from 1970 to 2015 as the adhesion to the treaty has started from 1978 (which is also the modal year of the event). Top 5% income inequality is found to increase by 0.75-1.00% in a 5-year horizon after the event, which is statistically significant at a 95% confidence level. This corresponds to a log-increase of 0.034-0.046 with respect to the average value of inequality (20.1%) which, as expected, is (slightly) lower than the long-run elasticity yielded by the ECM regression, 0.053 (col. 3, Table 2).

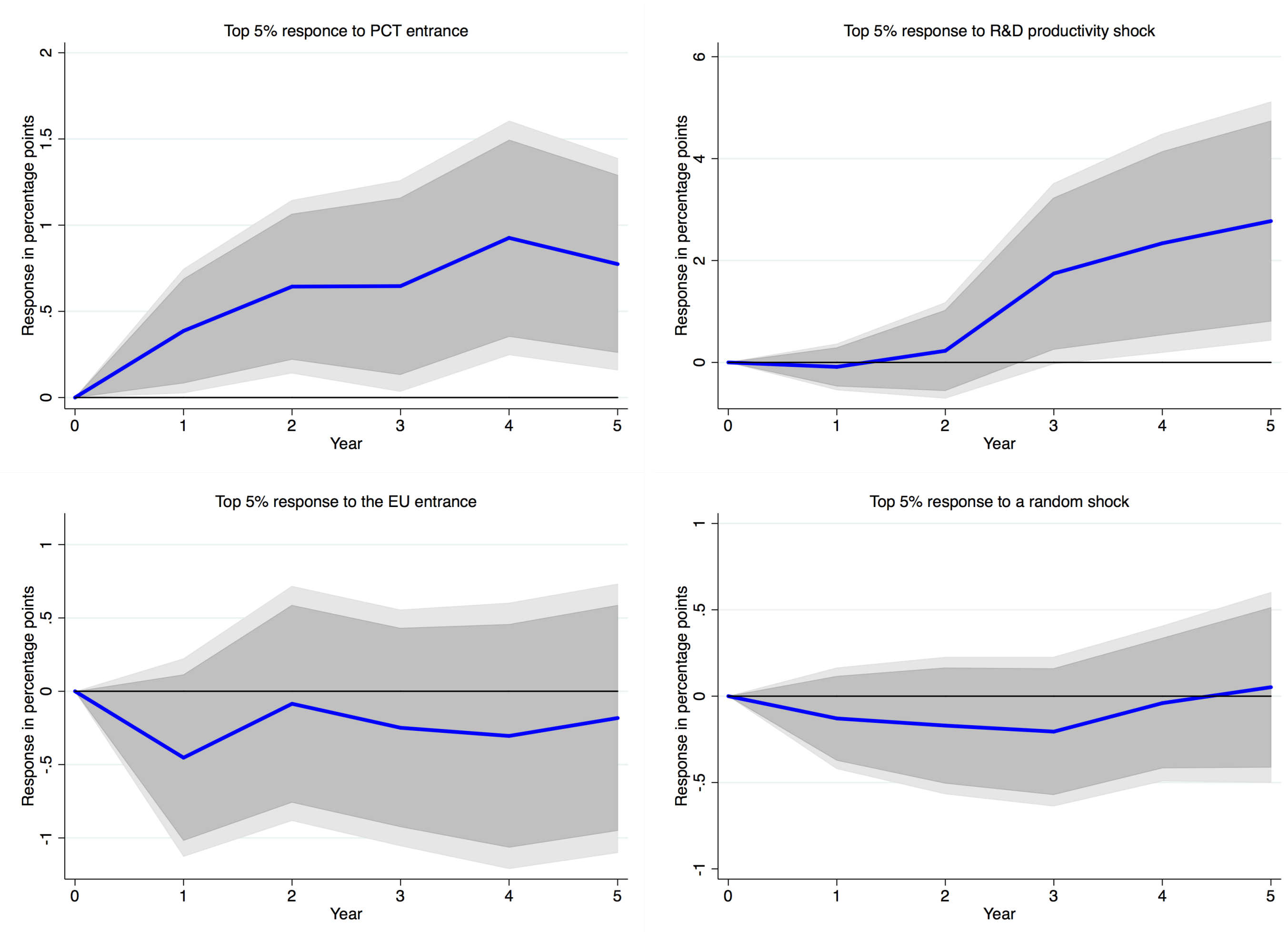
As a confirmation of the response of income inequality to technology shocks, we simulate how top 5% income share evolves after a peak year in research productivity. In this case, the event variable is defined as a dummy of unitary value in the year in which the ratio between patent counts and adjusted research input achieves its maximum value between 1970 and 2015 (see Jordá and Taylor, 2016 for a discussion on the use of this type of indicators in LP). In this exercise, the response function is similar to the one yielded considering the PCT entrance as event. Five years after the R&D efficiency peak,

[12] The reader is refereed to Figure B1 of Appendix B for LP results on the full set of inequality indicators.

top income inequality is about 2 percentage point larger than the pre-event period, corresponding to a 0.092 log-increase.

Furthermore, we perform a counter-factual exercise and simulate the response of income inequality to (i) the entrance of (some countries) into the European Union in which time span varies from 1950 to 2015; and (ii) a random shock in which the event year is identified randomly. In either case, the shape of the response function is considerably different from above and no statistically significant change is found in the dynamics of top 5% income share.

Figure 3: **Top 5% income share response to PCT and alternative shocks**



Notes: LP coefficient estimates (α_{1k}). Bands in light and dark grey identify 90 and 95% confidence intervals, based on Eicker-Huber-White heteroskedasticity-robust standard errors. The reported values correspond to the absolute change in the inequality indicator (Y-axis) over a 5-year horizon (X-axis). Regressions use annual data from 1970 to 2015, except for the event analysis on the EU membership which is based on data from 1950 to 2015.

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Appendix A

A.1 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 $U^d(x)$ under the asset-accumulation equation 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 $U^f(x)$ under the asset-accumulation equation taking $\{r_t^f, w_t^f\}$ as given;

3. Competitive consumption-good firms in the domestic country produce $\{Y_t^d\}$ to maximize profits taking $\{P_{yt}^{dd}, P_{yt}^{df}\}$ as given;

4. Competitive consumption-good firms in the foreign country produce $\{Y_t^f\}$ to maximize profits taking $\{P_{yt}^{ff}, P_{yt}^{fd}\}$ as given;

5. Competitive final-good firms in the domestic country produce $\{Y_t^{dd}, Y_t^{df}\}$ to maximize profits taking $\{P_{yt}^{dd}, P_t^{df}, p_{xt}^{dd}, p_{xt}^{df}\}$ as given;

6. Competitive final-good firms in the foreign country produce $\{Y_t^{ff}, Y_t^{fd}\}$ to maximize profits taking $\{P_{yt}^{ff}, P_t^{fd}, p_{xt}^{ff}, p_{xt}^{fd}\}$ 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 $\iota \in [0, 1]$ in the domestic country devotes $\{R_t^d(\iota)\}$ units of final goods to R&D to maximize expected profits taking $\{v_t^d\}$ as given;

10. Competitive R&D entrepreneur $\iota \in [0, 1]$ in the foreign country devotes $\{R_t^f(\iota)\}$ 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 $L_t^d = L_{xt}^d = \int_0^1 L_{xt}^d(i)\mathrm{d}i$ and $L_t^f = L_{xt}^f = \int_0^1 L_{xt}^f(i)\mathrm{d}i$;

13. The total value of household assets equals the value of monopolistic firms in each country so 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 value of trade in the intermediate goods is balanced such that $P_{yt}^{fd}Y_t^{fd} = P_{yt}^{df}Y_t^{df}$.

A.2 Equilibrium labor allocation

Given (8), the price indices for Y_t^{dd} and Y_t^{fd} are equal to $P_{yt}^{dd} = P_{yt}^{fd} = \psi w_t^d/Z_t^d$. Similarly, the price indices for Y_t^{ff} and Y_t^{df} write as $P_{yt}^{ff} = P_{yt}^{df} = \psi w_t^f/Z_t^f$. Using the conditional demand functions in country h for domestic and foreign final goods (5) yields:

$$\frac{P_{yt}^{dd}Y_t^{dd}}{\beta} = \frac{P_{yt}^{df}Y_t^{df}}{1-\beta} = \frac{P_{yt}^{fd}Y_t^{fd}}{1-\beta}, \tag{A1}$$

where the second equality of Eq. (A1) 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 $L_{xt}^{dd} + L_{xt}^{fd} = L_{xt}^d = L_t^d$ 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, using these results into (4), we get:

$$Y_t^d = (Z_t^d L_t^d)^{\beta}(Z_t^f L_t^f)^{1-\beta} = D_t^d \Omega_t^d. \tag{A2}$$

A.3 Model's dynamics

Using the balanced-trade condition $P_{yt}^{fd}Y_t^{fd} = P_{yt}^{df}Y_t^{df}$ into (9) and (10) gives:

$$\pi_t^d = \left(\frac{\psi-1}{\psi}\right)(P_{yt}^{dd}Y_t^{dd} + P_{yt}^{df}Y_t^{df}) = \left(\frac{\psi-1}{\psi}\right)Y_t^d, \tag{A3}$$

$$w_t^d L_{xt}^d = \frac{P_{yt}^{dd}Y_t^{dd} + P_{yt}^{df}Y_t^{df}}{\psi} = \frac{Y_t^d}{\psi}, \tag{A4}$$

where the second equality of (A3) and (A4) follows from (5). Using Eqs. (13), (A2) and (A3) and recalling that $v_t^d = a_t^d$ we get:

$$\frac{\dot{a}_t^d}{a_t^d} = \frac{\dot{v}_t^d}{v_t^d} = \frac{\dot{D}_t^d}{D_t^d} + \frac{\dot{\Omega}_t^d}{\Omega_t^d} = \frac{\dot{Y}_t^d}{Y_t^d} = \frac{\dot{\pi}_t^d}{\pi_t^d}, \tag{A5}$$

which shows that $\{a_t^d, v_t^d, Y_t^d, \pi_t^d\}$ grow 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. Using the market-clearing condition for final goods $Y_t^d = C_t^d + R_t^d$ into (14), we get:

$$\lambda_t^d = \vartheta^d\left(\frac{Y_t^d - C_t^d}{D_t^d\Omega_t^d}\right) = \vartheta^d(1-\Sigma_t^d), \tag{A6}$$

where the second equality uses $Y_t^d = D_t^d \Omega_t^d$ by Eq. (A2). As Eq. (A6) shows, the dynamics of λ_t^d is entirely determined by Σ_t^d. Taking the log of Σ_t^d and differentiating it with respect to t gives:

$$\frac{\dot{\Sigma}_t^d}{\Sigma_t^d} = \frac{\dot{C}_t^d}{C_t^d} - \frac{\dot{D}_t^d}{D_t^d} - \frac{\dot{\Omega}_t^d}{\Omega_t^d} = r_t^d - \rho - \frac{\dot{v}_t^d}{v_t^d}, \tag{A7}$$

where the second equality uses the Euler equation (3) 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. (A5). Substituting r_t^d from (11) into (A7) and noticing that $\pi_t^d = v_t^d \vartheta^d (\psi - 1)/\psi$ by Eqs. (A2), (A3) and (13), we get:

$$\frac{\dot{\Sigma}_t^d}{\Sigma_t^d} = \frac{(\psi - 1)}{\psi} \vartheta^d - \lambda_t^d - \rho. \tag{A8}$$

Then, replacing λ_t^d from (A6) into (A8) yields a one-dimensional differential equation for Σ_t^d, namely:

$$\frac{\dot{\Sigma}_t^d}{\Sigma_t^d} = \vartheta^d \Sigma_t^d - \rho - \frac{\vartheta^d}{\psi}. \tag{A9}$$

Since the coefficient on Σ_t^d in (A9), namely ϑ^d, is positive, the dynamics of Σ_t^d is 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 into (A6) 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. (A2) implies that C_t^d must grow at the same rate of Y_t^d. We finally prove that $\Omega_t^d \equiv (L_t^d)^\beta (L_t^f)^{1-\beta}$ is stationary as well. Rewriting Eq. (2) as $\theta C_t^d = w_t^d (1 - L_t^d)$ and then dividing both sides of this equation by Y_t^d yield:

$$\theta \frac{C_t^d}{Y_t^d} = \theta \Sigma^d = \frac{w_t^d}{Y_t^d} - \frac{w_t^d L_t^d}{Y_t^d}, \tag{A10}$$

where the first equality uses the fact that $Y_t^d = D_t^d \Omega_t^d$ by Eq. (A2). Replacing $w_t^d L_{xt}^d$ from (A4) into (A10) and noticing that $L_t^d = L_{xt}^d$ yield $w_t^d / Y_t^d = \theta \Sigma^d + 1/\psi$, which implies that $\dot{w}_t^d / w_t^d = \dot{Y}_t^d / Y_t^d$. Then, taking the log of (A4) and differentiating the resulting equation with respect to t yield:

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

which shows that labor supply in the domestic economy, L_t^d, must be stationary.

$$L_t^d = 1 - \sigma \frac{C_t^d}{w_t^d} = 1 - \sigma \frac{C_t^d}{Y_t^d} \frac{Y_t^d}{w_t^d} = 1 - \sigma \frac{\Sigma^d}{\sigma \Sigma^d + 1/\psi} = \frac{1}{1 + \sigma + \sigma \rho \psi / \vartheta^d}.$$

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 into (A5), 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.4 Wealth distribution

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

$$\dot{a}_t^d = r_t^d a_t^d + w_t^d L_t^d - C_t^d. \tag{A11}$$

Combining (1) with (A11), the law of motion of $\phi_{at}^d(x) \equiv a_t^d(x)/a_t^d$ can be written as:

$$\dot{\phi}_{at}^d(x) = \frac{w_t^d L_t^d}{a_t^d}\phi_{lt}^d(x) - \frac{C_t^d}{a_t^d}\phi_{ct}^d(x) - \frac{(w_t^d L_t^d - C_t^d)}{a_t^d}\phi_{at}^d(x), \tag{A12}$$

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. (13), (A2), (A4) and $v_t^d = a_t^d$ and recalling that the aggregate economy is always on the balanced growth path along which $\Sigma_t^d \equiv C_t^d/(D_t^d\Omega_t^d) = \rho/\vartheta^d + 1/\psi$, after some rearranging, we get:

$$\frac{w_t^d L_t^d}{a_t^d} = \frac{\vartheta^d}{\psi}, \qquad \frac{C_t^d}{a_t^d} = \rho + \frac{\vartheta^d}{\psi}. \tag{A13}$$

Moreover, using Eq. (2), we can express $\phi_{lt}^d(x)$ as:

$$\phi_{lt}^d(x) = \frac{w_t^d - \theta c_t^d(x)}{w_t^d - \theta C_t^d} = \frac{\frac{w_t^d}{Y_t^d} - \theta\frac{C_t^d}{Y_t^d}\phi_{ct}^d(x)}{\frac{w_t^d}{Y_t^d} - \theta\frac{C_t^d}{Y_t^d}} = \frac{\theta\psi}{\vartheta^d}\left(\rho + \frac{\vartheta^d}{\psi}\right)\left[1 - \phi_{ct}^d(x)\right] + 1, \tag{A14}$$

where the third equality of (A14) 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. (A13) and (A14) into (A12) and noticing that $\phi_{ct}^d(x) = \phi_{c0}^d(x)$ for all $t > 0$ by Eq. (3) yield:

$$\dot{\phi}_{at}^d(x) = \rho\phi_{at}^d(x) + \frac{\vartheta^d}{\psi} + \left(\rho + \frac{\vartheta^d}{\psi}\right)\left\{\left[\theta(1 - \phi_{c0}^d(x)\right] - \phi_{c0}^d(x)\right\}. \tag{A15}$$

The coefficient on ϕ_{at}^d, namely ρ, is positive. Thus, the only solution of the differential equation (A15) 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:

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

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).

A.5 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 and replacing household x's labor supply, $l_t^d(x) = 1 - \theta c_t^d(x)/w_t^d$, into Eq. (1), yield:

$$c_t^d(x) = \frac{a_t^d(x)(r_t^d - g^d) + w_t^d}{\theta+1}, \qquad l_t^d(x) = \frac{1 - \theta(r_t^d - g^d)a_t^d(x)/w_t^d}{\theta+1}. \tag{A16}$$

Substituting $l_t^d(x)$ from (A16) into household x's income, $I_t^d(x) = r_t^d a_t^d(x) + w_t^d l_t^d(x)$, we get:

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

which implies that the aggregate level of income amounts to $I_t^d = [(r_t^d + \theta g^d)a_t^d + w_t^d]/(\theta + 1)$. Using these results, the share of income earned by household x, $\phi_{It}^d(x) \equiv I_t^d(x)/I_t^d$, can be written as:

$$\phi_{It}^d(x) = \frac{(r_t^d + \theta g^d)a_t^d \phi_{a0}^d(x) + w_t^d}{(r_t^d + \theta g^d)a_t^d + w_t^d},$$

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 income share is:

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

with the interest rate, r_t^d, equal to $r^d = g^d + \rho$, the growth rate, g^d, given by Eq. (15) and, finally, the asset-wage ratio, a_t^d/w_t^d, equal to:

$$\frac{a_t^d}{w_t^d} = \frac{Y_t^d}{\vartheta^d w_t^d} = \frac{1}{\vartheta^d}\frac{1}{(\theta\Sigma^d + 1/\psi)} = \frac{1}{\theta\rho + (\theta + 1)\vartheta^d/\psi}. \quad \text{(A17)}$$

Notice that the first equality of (A17) uses the fact that $a_t^d = v_t^d = Y_t^d/\vartheta^d$ by Eq. (13), whereas the second equality exploits the fact that the wage-income ratio, w_t^d/Y_t^d, amounts to $\theta\Sigma^d + 1/\psi$ in steady state.

Appendix B

Table B1: **Effects across time intervals**

	(1)	(2)	(3)	(4)
	1920-2015	1950-2015	1980-2015	1980-2015
		R&D		**IPP**
		CAPITAL SHARE		
Research productivity	0.071***	0.026***	0.024***	0.016***
	(0.002)	(0.004)	(0.004)	(0.004)
Obs.	1,560	1,214	660	660
R-squared	0.913	0.834	0.837	0.848
		TOP 0.1% INCOME SHARE		
		TOP 0.1%		
Research productivity	0.086***	0.097***	0.133***	0.175***
	(0.008)	(0.015)	(0.018)	(0.022)
Obs.	1,710	1,250	651	651
R-squared	0.880	0.786	0.777	0.770
		TOP 1% INCOME SHARE		
Research productivity	0.054***	0.014	0.092***	0.120***
	(0.005)	(0.009)	(0.014)	(0.016)
Obs.	1,710	1,250	651	651
R-squared	0.908	0.820	0.738	0.740
		TOP 10% INCOME SHARE		
Research productivity	0.014***	0.011**	0.032***	0.036***
	(0.003)	(0.005)	(0.008)	(0.008)
Observations	1,710	1,250	651	651
R-squared	0.895	0.830	0.782	0.767

Notes: Long-run estimates derived from a panel Error Correction Mechanism specification. All variables are expressed in logs. Estimates include country-specific fixed effects and common correlated effects (CCE). The number of time lags for first-difference regressors and CCEs is set to 5. Newey-West standard errors in parantheses. Research productivity is measured as the ratio between patent counts and adjusted R&D expenses in cols. (1)-(3), and between patent counts and IPP expenditure in col. (4). Real R&D (or IPP) expenses are discounted by a difficulty index defined as the product between TFP and population. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table B2: **Robustness estimates: measurement issues** (1920-2015)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					FACTOR INCOME RATIO				
Research productivity	0.182***	0.151***	0.024***	0.030***	0.195***	0.174***	0.037***	0.097***	0.157***
	(0.006)	(0.004)	(0.005)	(0.004)	(0.004)	(0.006)	(0.004)	(0.005)	(0.006)
R-squared	0.937	0.960	0.949	0.940	0.963	0.940	0.929	0.940	0.940
					CAPITAL SHARE				
Research productivity	0.071***	0.126***	0.030***	0.023***	0.144***	0.077***	0.014***	0.040***	0.067***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
R-squared	0.913	0.920	0.917	0.903	0.929	0.909	0.918	0.918	0.912
					TOP 0.1% INCOME SHARE				
Research productivity	0.086***	0.062***	0.070***	0.031***	0.063***	0.084***	0.026***	0.046***	0.054***
	(0.008)	(0.004)	(0.004)	(0.003)	(0.004)	(0.008)	(0.005)	(0.006)	(0.008)
R-squared	0.880	0.874	0.871	0.871	0.875	0.881	0.879	0.873	0.885
					TOP 1% INCOME SHARE				
Research productivity	0.054***	0.051***	0.057***	0.020***	0.063***	0.051***	0.023***	0.027***	0.023***
	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.003)	(0.004)	(0.005)
R-squared	0.908	0.907	0.906	0.895	0.904	0.908	0.902	0.900	0.904
					TOP 10% INCOME SHARE				
Research productivity	0.014***	0.024***	0.026***	0.010***	0.031***	0.012***	0.005***	0.014***	-0.007*
	(0.003)	(0.002)	(0.002)	(0.001)	(0.002)	(0.003)	(0.002)	(0.003)	(0.004)
R-squared	0.895	0.893	0.890	0.892	0.892	0.895	0.900	0.895	0.895
					GINI				
Research productivity	0.011***	0.003	0.005***	-0.002**	0.002	0.010***	-0.001	0.008***	0.001
	(0.003)	(0.002)	(0.002)	(0.001)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)
R-squared	0.881	0.885	0.896	0.905	0.890	0.883	0.889	0.889	0.891
Patent data source	WIPO	USPTO	USPTO	USPTO	USPTO	WIPO	WIPO	WIPO	WIPO
Patent indicator	Counts	Counts	Fwc cites × counts	Originality × counts	Generality × counts	Counts	Counts	Counts	Counts
R&D difficulty	TFP × POP	TFP × POP	TFP × POP	TFP × POP	TFP × POP	TFP	Trademark	Quality jump	None

Notes: Long-run estimates derived from a panel Error Correction Mechanism specification. All variables are expressed in logs. Estimates include country-specific fixed effects and common correlated effects (CCE). The number of time lags for first-difference regressors and CCEs is set to 5. Newey-West standard errors in parantheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table B3: **Full set of estimates with controls** (1920-2015)

	(1)	(2) Unem-ployment rate	(3) Tax burden on GDP	(4) Popula-tion growth	(5) Import penetra-tion	(6) Inflation rate	(7) Labor produc-tivity	(8) Tobin's Q	(9) Bank credit / GDP	(10) Tertiary educa-tion
					FACTOR INCOME RATIO (obs.=1,560)					
Research productivity	0.182***	0.120***	0.097***	0.164***	0.179***	0.118***	0.190***	0.223***	0.089***	0.090***
	(0.006)	(0.009)	(0.008)	(0.009)	(0.007)	(0.007)	(0.008)	(0.006)	(0.008)	(0.006)
Control		-0.005	-0.333***	0.070***	-0.235***	0.005***	-0.544***	0.240***	0.472***	-0.474***
		(0.008)	(0.031)	(0.011)	(0.020)	(0.001)	(0.049)	(0.017)	(0.027)	(0.107)
R-squared	0.937	0.860	0.850	0.895	0.892	0.922	0.887	0.909	0.868	0.875
					CAPITAL SHARE (obs.=1,560)					
Research productivity	0.071***	0.054***	0.045***	0.139***	0.065***	0.049***	0.105***	0.071***	0.037***	0.029***
	(0.002)	(0.004)	(0.004)	(0.004)	(0.003)	(0.002)	(0.003)	(0.002)	(0.004)	(0.003)
Control		0.008**	-0.169***	0.159***	-0.103***	0.001***	-0.167***	0.262***	0.355***	-0.312***
		(0.003)	(0.015)	(0.006)	(0.009)	(0.000)	(0.018)	(0.009)	(0.014)	(0.052)
R-squared	0.913	0.857	0.843	0.888	0.883	0.910	0.881	0.886	0.882	0.891
					TOP 0.1% INCOME SHARE (obs.=1,710)					
Research productivity	0.086***	0.066***	0.100***	0.098***	0.108***	0.128***	0.065***	0.100***	0.062***	0.091***
	(0.008)	(0.010)	(0.010)	(0.010)	(0.008)	(0.009)	(0.010)	(0.008)	(0.010)	(0.011)
Control		0.053***	-0.139***	0.109***	0.208***	-0.006***	0.112**	-0.046***	0.020	-0.686***
		(0.009)	(0.015)	(0.012)	(0.030)	(0.001)	(0.046)	(0.014)	(0.013)	(0.128)
R-squared	0.880	0.845	0.847	0.832	0.837	0.808	0.822	0.863	0.836	0.856
					TOP 1% INCOME SHARE (obs.=1,710)					
Research productivity	0.054***	0.033***	0.048***	0.089***	0.077***	0.096***	0.089***	0.057***	0.029***	0.078***
	(0.005)	(0.007)	(0.008)	(0.007)	(0.005)	(0.006)	(0.007)	(0.005)	(0.006)	(0.006)
Control		0.001	-0.131***	0.027***	0.114***	-0.006***	-0.270***	0.004	0.132***	-0.198*
		(0.006)	(0.011)	(0.009)	(0.015)	(0.001)	(0.035)	(0.010)	(0.010)	(0.104)
R-squared	0.908	0.832	0.855	0.846	0.876	0.859	0.825	0.895	0.852	0.886
					TOP 10% INCOME SHARE (obs.=1,710)					
Research productivity	0.014***	0.003	0.022***	0.024***	0.033***	0.012***	0.025***	0.015***	-0.001	0.034***
	(0.003)	(0.004)	(0.006)	(0.004)	(0.003)	(0.004)	(0.005)	(0.003)	(0.004)	(0.004)
Control		-0.015***	-0.088***	0.029***	0.029***	-0.002***	-0.036	-0.033***	0.041***	-0.067
		(0.004)	(0.008)	(0.006)	(0.009)	(0.001)	(0.026)	(0.007)	(0.006)	(0.045)
R-squared	0.895	0.814	0.844	0.837	0.839	0.859	0.845	0.872	0.841	0.875
					GINI (obs.=1,1668)					
Research productivity	0.011***	-0.017***	-0.019***	0.013***	-0.001	0.033***	-0.003	0.001	0.005*	0.027***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Control		-0.015***	-0.024***	-0.018***	0.097***	0.004***	-0.006	-0.004	-0.003	0.397***
		(0.003)	(0.005)	(0.004)	(0.009)	(0.000)	(0.014)	(0.004)	(0.004)	(0.037)
Obs.	1,668	1,648	1,668	1,668	1,668	1,668	1,668	1,668	1,668	1,668
R-squared	0.881	0.865	0.864	0.866	0.872	0.848	0.822	0.890	0.819	0.846

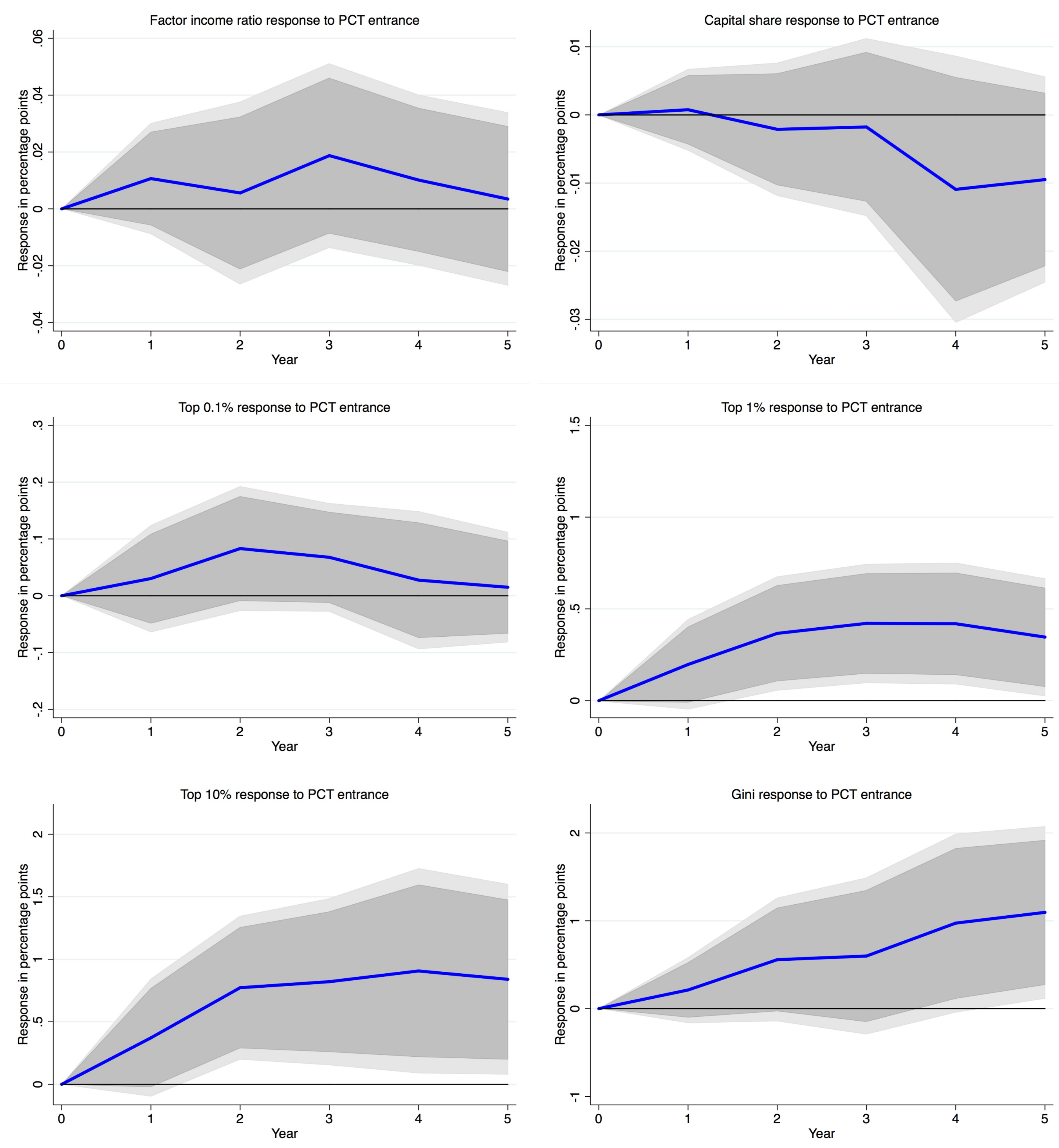
Notes: Long-run estimates derived from a panel Error Correction Mechanism specification. All variables are expressed in logs. Estimates include country-specific fixed effects and common correlated effects (CCE). The number of time lags for first-difference regressors and CCEs is set to 5. Newey-West standard errors in parantheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table B4: **Full set of open-economy regressions** (1920-2015)

	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	FACTOR INCOME RATIO				**CAPITAL SHARE**			
Domestic research productivity	0.182***	0.133***	0.100***	0.189***	0.071***	0.031***	0.022***	0.042***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.002)	(0.003)	(0.002)	(0.002)
Foreign research productivity		0.067	0.029	0.061		0.052**	0.014	-0.088***
		(0.045)	(0.040)	(0.042)		(0.023)	(0.015)	(0.018)
Domestic quality jump			0.006**				0.001	
			(0.003)				(0.001)	
Domestic exit rate				0.048*				-0.050***
				(0.028)				(0.011)
Obs.	1,560	1,560	1,480	1,560	1,560	1,560	1,480	1,560
R-squared	0.937	0.922	0.833	0.908	0.913	0.902	0.809	0.896
	TOP 0.1%				**TOP 1%**			
Domestic research productivity	0.086***	0.078***	0.087***	0.025**	0.054***	0.043***	0.051***	-0.012*
	(0.008)	(0.008)	(0.009)	(0.011)	(0.005)	(0.005)	(0.006)	(0.007)
Foreign research productivity		0.182***	0.483***	0.050***		0.077***	0.226***	0.071***
		(0.017)	(0.033)	(0.013)		(0.009)	(0.019)	(0.010)
Domestic quality jump			0.022***				0.003	
			(0.003)				(0.002)	
Domestic Exit rate				-0.231***				-0.101***
				(0.024)				(0.017)
Obs.	1,710	1,710	1,605	1,710	1,710	1,710	1,605	1,710
R-squared	0.880	0.877	0.837	0.834	0.908	0.902	0.888	0.859
	TOP 10%				**GINI**			
Domestic research productivity	0.014***	0.008**	0.007*	-0.015***	0.011***	-0.030***	-0.023***	-0.000
	(0.003)	(0.004)	(0.004)	(0.005)	(0.003)	(0.003)	(0.003)	(0.004)
Foreign research productivity		0.008	0.100***	0.025***		0.021***	0.032***	0.008
		(0.007)	(0.015)	(0.007)		(0.005)	(0.007)	(0.006)
Domestic quality jump			0.002				-0.005***	
			(0.001)				(0.001)	
Domestic Exit rate				0.064***				0.003
				(0.010)				(0.008)
Observations	1,710	1,710	1,605	1,710	1,668	1,668	1,563	1,668
R-squared	0.895	0.897	0.875	0.859	0.881	0.861	0.858	0.843

Notes: Long-run estimates derived from a panel Error Correction Mechanism specification. All variables are expressed in logs. Estimates include country-specific fixed effects and common correlated effects (CCE). The number of time lags for first-difference regressors and CCEs is set to 5. Newey-West standard errors in parantheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure B1: **Full set of inequality responses to PCT entrance**



Notes: LP coefficient estimates (α_{1k}). Bands in light and dark grey identify 90 and 95% confidence intervals, based on Eicker-Huber-White heteroskedasticity-robust standard errors. The reported values correspond to the absolute change in the inequality indicator (Y-axis) over a 5-year horizon (X-axis). Regressions use annual data from 1970 to 2015.