# When Aiyagari meets Piketty: Growth, Inequality and Capital Shares*

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**Abstract**

We incorporate the division of income between capital and labor into analysis on the relationship between inequality and growth. Using historical data, we document that changes in the top 1 % income shares are positively associated with subsequent growth of per capita GDP when the capital share of income is low, whereas under high capital share, the association is negative. We show that these findings are compatible with a theoretical analysis that emphasises how changes in the distribution of income translate into the accumulation of capital and overall economic activity through the interplay between precautionary saving motives and consumption smoothing. We also investigate how accounting for financial frictions affects our main findings.

**Keywords:** Economic growth, Inequality, Top income shares, Capital shares

**JEL Codes:** D31, E21, E25, O15

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# 1 Introduction

The interplay between overall economic activity, the distribution of personal income and the division of total national income between factors of production has fascinated economists since the early days of the discipline. Currently, the reported changes in inequality and functional income distribution makes the question increasingly topical. During the past 30 years, many theoretical studies have suggested channels through which economic inequality affects economic growth, and to accompany the theoretical work on the subject, numerous empirical papers using cross-country datasets have emerged. While numerous theoretical studies have challenged the traditional views that inequality enhances growth through economic incentives and higher savings rate of the rich[1], empirical evidence remains inconclusive.

In this study, we contribute to the vast literature about the relationship between economic inequality and growth. We show both theoretically and empirically that the association between growth and income inequality is conditional on the division of income between capital and labor, i.e. the functional income distribution. Although the linkages between personal and functional income distributions have been widely-studied (Daudey and García-Peñalosa, 2007; Atkinson, 2009; Checchi and García-Peñalosa, 2010; Piketty, 2014; Milanovic, 2016b; Bengtsson and Waldenström, 2018), and there is also some research on the interplay between functional income distribution and growth (Charpe et al., 2019), we are unaware of previous studies that would have examined functional income distribution as a potential determinant of the inequality-growth relationship.

Our theoretical analysis builds on the seminal study by Aiyagari (1994). We adopt Aiyagari's (1994) model and follow the original model specification and parameterization to innovatively examine the responses of economic growth to an inequality shock conditional on the level of capital share of total income. Our main theoretical prediction is that an increase

[1]Most notable studies on the growth-dampening effects of inequality include Galor and Zeira (1993), Alesina and Rodrik (1994), Persson and Tabellini (1994), Alesina and Perotti (1996) and Galor and Moav (2004). See Kaldor (1957) and Bourguignon (1981) on convex savings function ("the rich save more"). In Section 2, we present the main feature of these studies, and also review the previous empirical literature on the topic.

in income inequality is associated with higher subsequent economic growth when labor is the dominant factor of production in the economy. On the contrary, when the capital share of income is large, an increase in inequality is related with lower growth. This prediction holds when credit constraint is sufficiently low.

In terms of mechanisms, our theoretical analysis stresses the accumulation of physical capital in a simple capital market equilibrium. The dependency of the inequality-growth relationship to functional income distribution stems from the interplay between precautionary motives and consumption smoothing. For low capital shares, the precautionary motives dominate, and as a result, an increase in income inequality leads into higher capital supply and higher per capita growth. For high capital shares in turn, the consumption smoothing effect dominates resulting in a negative link between increasing inequality and capital supply, which eventually hurts growth in our Aiyagari (1994) type economy. The previous holds when credit constraint is low, whereas if the households cannot borrow as easily, precautionary motives dominate consumption smoothing for all values of capital share. Consequently, under high credit constraint, our model predicts that income inequality is positively associated with growth irrespective of the distribution of income between capital and labor.

Our empirical findings align with our theoretical predictions. Our results reveal that the association between changes in the top 1 % income share and subsequent growth rates is i) positive when the capital share of income is low, and ii) negative when the capital share of income is high. Furthermore, based on various measures of financial development, we seek to build a bridge between theory's credit constraint and measurable evolutions. Namely, we show that, like in the full sample, the inequality-growth relationship depends on the capital share during eras of high financial development, whereas this dependency is not present in the data during low financial development.

We obtain these empirical results by relying on panel data from 13 developed countries that span over the period 1895-2014. The data come from a study by Bengtsson and Waldenström (2018), whose work is closely related to the influential book by Piketty (2014). For financial development, we resort to Rajan and Zingales (2003). Our panel regressions focus on five-year non-overlapping windows, which has been a typical approach in previous studies, to investigate how the growth of per capita GDP depends on the top income shares and the capital share of total national income while controlling for the level of economic development and fixed country and year effects. Our results are robust to numerous robustness checks.

Our contribution to the existing literature is threefold. First, using historical data on distributional measures and per capita GDP, we reveal a previously undiscovered robust association between personal and functional income distributions and per capita growth. Second, we introduce a novel theoretical link between the distribution of income, capital accumulation and growth. Furthermore, the focal results of our theoretical and empirical analysis are in line with one another. Third, we demonstrate the role of financial frictions as an underlying determinant for the nature of the relationship between the distribution of income – both personal and functional – and economic growth.

The structure of the study is the following. In Section 2, we provide the central previous literature from the perspective of our theoretical model and empirical approach. We present our theoretical model in Section 3, dedicate Section 4 for the empirical analysis and, finally, conclude our findings in Section 5.

# 2 Literature review

Our study contributes to several branches of previous economic literature on income distribution and real growth, and in particular the interplay of the two. First, in Section 3, we illustrate the dependency of the inequality-growth nexus to functional income distribution by adopting the seminal theoretical model by Aiyagari (1994). In an Aiyagari economy the aggregate capital demand is given by a representative firm and the aggregate capital supply is endogenously determined by the saving decisions of households (Aiyagari, 1994; Bewley, 1983). In the steady state capital market equilibrium, the marginal productivity of capital gives the slope for the demand curve for the real productive capital, whereas the supply of capital is determined subject to precautionary motives and borrowing constraints of households (Aiyagari, 1994; Huggett, 1993).

In early studies, Sibley (1975) and Miller (1975) showed that under a concave periodic utility function a mean-preserving spread in the income distribution increases the savings of each households in long horizons. In Aiyagari's model, this can be interpreted as an increased income uncertainty, which increases precautionary motives. However, it is not clear whether the precautionary savings will increase the aggregate capital supply, due to the assumed stationary distribution of total resources. In our theoretical analysis, we exploit this curiosity in the determination of the capital market equilibrium to investigate how the relationship between income inequality and growth is conditional on the marginal productivity of capital and the capital share.[2]

The inequality-growth relationship has been previously analyzed using theoretical frameworks other than the one discussed above. Next, we present the main features of some notable studies on the topic. The conventional view is that inequality enhances economic incentives and consequently promotes economic growth. Another traditional argument states that because the savings rate of the rich is larger than that of the poor (i.e. the savings function is convex), economies with more unequal income distribution tend to save more and experience faster economic growth (Kaldor, 1957; Bourguignon, 1981). Furthermore, in the absence of sufficiently developed financial markets and institutions, some level of inequality may be needed for entrepreneurial individuals to cover the set-up costs for a new firm (Aghion et al., 1999). Thus, according to this argument too, inequality fosters growth.

Aghion et al. (1999) pointed out that development economists have long presented informal counterarguments to the views that inequality enhances growth. Starting from the 1990s, numerous authors have developed these arguments into theoretical models. One of the most influential models was constructed by Galor and Zeira (1993): under credit fric-

[2]See Quadrini et al. (1997) and Benhabib and Bisin (2018) for detailed overview of the theoretical studies on the distribution of wealth.

tions, individual level investment in human capital is determined by inherited wealth, and consequently, inequality dampens the aggregate level human capital accumulation and economic growth. More recently, Galor and Moav (2004) developed a model, where human capital replaces physical capital as a prime growth engine during the process of economic development. In the early stages of development, when the accumulation of physical capital drives growth, the convex savings function mechanism dominates and inequality is growth-enhancing. Later on, the human capital channel takes the dominant role and inequality is bound to dampen growth.

Two additional channels through which inequality may hurt growth involve the leaky bucket metaphor and sociopolitical instability. In brief, the former states that, due to the need of redistribution, higher inequality leads to higher taxation and lower economic growth. The idea of a leaky bucket was introduced by Okun (1975): "The money must be carried from the rich to the poor in a leaky bucket. Some of it will simply disappear in transit, so the poor will not receive all the money that is taken from the rich". The concept was further developed by Alesina and Rodrik (1994) and Persson and Tabellini (1994). The role of sociopolitical instability was formalized by Alesina and Perotti (1996), who argue that, by fueling social discontent, inequality induces instability that is harmful for investments and overall economic activity.

Datawise, we anchor ourselves firmly to the bestselling book *Capital in the Twenty-First Century* by Piketty (2014) and to the work by dozens of other scholars, whose pioneering effort is gathered in the World Inequality Database.[3] As illustrated in Figures 4 and 5 in Section 4.1 of this study, the top income shares and capital shares declined from the early twentieth century to the 1970s, whereas during the past 40 years, the shares have risen in many countries.[4]

[3]See `https://wid.world/methodology/` for an extensive list of studies.

[4]Analyzing the drivers of inequality, the changes in the functional income distribution or the link between the two are beyond the scope of this study. Seminal work on inequality include, among many others, Kuznets (1955) on inequality during economic development, Goldin and Katz (2009) on the supply and demand of educated workers and technological progress, Piketty (2014) on the difference between the return on capital and economic growth ($r - g$), and Milanovic (2016a) on the so-called Kuznets waves. Furthermore and

Finally, by adopting a standard panel regression approach for the empirical analysis in Section 4, our study contributes to the empirical reduced-form studies that have examined whether income inequality enhances or dampens economic growth. In their meta-analysis, Neves et al. (2016) review 28 studies that were published between 1994 and 2014. The first wave of studies relied on a cross-sectional data structure. More recently, researchers have predominantly used panel data and started to apply techniques (variants of generalized method of moments, GMM[5]) that aim to separate causation from correlation. Perhaps the most interesting finding of the meta-analysis is evidence for publication bias, i.e. statistically significant results are more willingly reported and published. Also, positive and negative estimates tend to be cyclically reported. Furthermore, the findings suggest that the estimation technique, data quality and the specification choice for the growth regression are not significant drivers of the varying estimates. Rather, cross-sectional analyses tend to find a stronger negative association than panel studies, the negative association is stronger in less developed countries, the inclusion of regional dummies soak up much of the previous finding and the concept of inequality significantly affects the results.

Even though the number of empirical studies is vast, a few have made a particularly strong impact. The cross-sectional studies by Alesina and Rodrik (1994) and Perotti (1996) found

interestingly for us, who use data on top income shares, Piketty and Saez (2003) found that the rising top income shares in the United States were largely driven by wage income in the late twentieth century, whereas during the twenty-first century, the role of capital income has strengthened (Piketty et al., 2018). Smith et al. (2019) documented that top earners in the US tend to derive their income mostly from human – rather than financial – capital. The recent increases in capital shares have been suggested to stem e.g. from the declining relative prices of investment goods (Karabarbounis and Neiman, 2013), technological progress and automation (Acemoglu and Restrepo, 2018), the loss of labor unions' bargaining power (Stansbury and Summers, 2020) and the rise of superstar firms (Autor et al., 2020). Piketty (2014) sees the connection between personal and functional income distributions straight-forwardly and argues that since capital income tends to be more unevenly distributed than labor income, rising capital share (or falling labor share) of income is positively associated with income inequality. Bengtsson and Waldenström (2018), whose data we use in this study, found long run evidence on this positive linkage, Atkinson (2009) discussed the relevance of studying factor shares and offers an analytical framework to assess the association between functional income distribution and personal income inequality while Milanovic (2016b) derived the conditions for the positive association to prevail. Further empirical evidence on the positive association between functional income distribution and income inequality was provided by Daudey and García-Peñalosa (2007) and by Checchi and García-Peñalosa (2010) while Civardi and Lenti (2018) link the two in a framework that follows the work of Atkinson (2009).

[5]See Bazzi and Clemens (2013) and Kraay (2015) for critique on the weakness of the instrument variables when the popular system GMM estimator is used.

evidence for growth-hurting inequality. Barro's (2000) findings suggested that the association between inequality and growth is negative for low levels of economic development and positive for high ones. Banerjee and Duflo (2003) showed that changes in inequality in any direction are associated with lower subsequent growth rates. Voitchovsky (2005) found that inequality at the top end of the income distribution supports economic activity while inequality at the bottom dampens growth. Halter et al. (2014) focused on the time dimension and found that inequality supports growth in the short-run but is harmful for economic performance farther in the future. Ostry et al. (2014) and Berg et al. (2018) take both inequality and redistribution. Their results suggest that inequality is bad for growth when redistribution is controlled for, whereas redistribution seems not to dampen growth.

Measure-wise, the Gini coefficient is by far the most used one in the empirical studies. However, the most extensively discussed inequality patterns are based on the top income shares (Piketty, 2014) rather than the broader measures such as the Gini.[6] Some of the few studies that analyze the relationship between the top income shares and growth are by Barro (2000), who investigated whether his results hold between different measures; by Andrews et al. (2011), whose findings suggested that during the latter half of the twentieth century, the top 10 % income share was positively associated with subsequent growth, while focusing on the entire century revealed no systematic pattern between top income shares and growth; by Herzer and Vollmer (2013), who focused on the level of per capita GDP and found that rising top income shares are bad for economic development; and by Thewissen (2014), whose results are similar to those of Andrews et al. (2011). To summarize, it is safe to say that no clear consensus emerges from the numerous empirical studies.

[6]Moreover, it is not clear that the Gini is the best available measure to distill the income distribution into a single number. Cobham et al. (2013) document that in countries at different income levels, the deciles 5–9 tend to capture roughly half of national income, whereas the shares going to the top 10 % and bottom 40 % vary considerably both in time and especially across countries. Thus, the authors suggest that the Palma ratio – defined as the ratio between the income share of the top 10 % and the income share of the bottom 40 % – would be a more relevant indicator than the Gini, which places a high weight on the middle incomes.

# 3 Theoretical model

This section of the study presents our theoretical analysis, which builds on the seminal study by Aiyagari (1994). First, we summarize the key features of Aiyagari (1994) with respect to our study. Second, we describe the modelling details and present the findings of our theoretical analysis.

In brief, we closely follow the model specification and parameterization by Aiyagari (1994). Our innovation is to analyze growth-responses to an inequality shock conditional on the division of income between capital and labor. Furthermore, we address the role of credit constraint in terms of the predictions of our model.

## 3.1 Aiyagari (1994)

We use Aiyagari's (1994) model to study the effects of an exogenous inequality shock on output and capital. In Aiyagari (1994), wealth inequality is endogenously determined by exogenously given labor endowment states and their transition probabilities. In our model, an exogenous inequality shock refers to a change in the labor endowment state space in the following way.

We increase, first, the expected value, and second, the variance of the labor endowment. Regarding the former, we increase the labor state for the top income brackets relatively more than for the poor, which is associated with increased productivity at the aggregate level. We label the effects related to the increased expected value of the labor endowment as *consumption smoothing effects*. Increasing the variance of the labor endowment generates an uncertainty shock, which makes the population more divergent. We call these effects as *precautionary savings effects*. It turns out that the two class of effects can be modeled only by changing the variance of the idiosyncratic labor endowment, and consequently, we compare the stationary equilibrium outcomes before and after an exogenous shock to labor endowment states.

Assume that there is a unit mass of infinitely lived households. Let $c_t$, $a_t$, and $\ell_t$ be a single household's consumption, assets, and labor endowment in period $t$. The labor endowment shocks are random and independent and identically distributed (i.i.d) over time with the cumulative probability distribution $F$ and support $[\ell_{min}, \ell_{max}]$ where $0 < \ell_{min} < \ell_{max} < \infty$. The utility in each period is given by $u(c_t)$ and it is discounted by $\beta = \frac{1}{1+\lambda} \in (0,1)$, where $\lambda$ is the rate of time preference. The utility function $u : \mathbb{R}_+ \to \mathbb{R}$ is continuously differentiable and bounded with derivatives $u'(c_t) > 0$, $u''(c_t) < 0$, $\lim_{c_t \to 0} u'(c_t) = \infty$, and $\lim_{c_t \to \infty} u'(c_t) = 0$. The household receives return $r$ on assets and wage $w \cdot \ell$ having labor endowment $\ell$. There is a borrowing limit $\underline{a}$ that makes the capital market incomplete.

All households are ex-ante symmetric and each of them solves the following recursive problem

$$V(a_t, \ell_t) = \max_{c_t, a_{t+1}} \left\{ u(c_t) + \beta \int_{\ell_{min}}^{\ell_{max}} V(a_{t+1}, \ell_{t+1}) dF(\ell_{t+1}) \right\} \tag{1}$$

subject to

$$a_{t+1} + c_t = (1 + r_t)a_t + w_t \ell_t, \tag{2}$$

$$a_t \geq \underline{a}, \qquad \text{almost surely} \tag{3}$$

$$c_t \geq 0, \tag{4}$$

$$c_0, k_0 \text{ given}, \tag{5}$$

where $V(a_t, \ell_t)$ is the value function in state $(a_t, \ell_t)$. The solution to this problem will include an optimal savings policy $a_{t+1} = g(a_t, \ell_t)$, an optimal consumption policy $c(a_t, \ell_t)$, and the value function $V(a_t, \ell_t)$.

A representative firm has a constant-returns-to-scale production technology $y_t = f(k_t, n_t)$, where $y_t$ is per-capita output, $k_t$ per-capita capital, and $n_t$ per-capita labor force. The equilibrium interest rate and wage level are given by the sufficient and necessary conditions of the firm's maximization problem

$$r_t = f_k(k_t, n_t) - \delta, \tag{6}$$

$$w_t = f_n(k_t, n_t). \tag{7}$$

The partial equilibria of the households' problems and the firm's problem constitute the general equilibrium of the model together with the total resource constraint $y_t = c_t + i_t$, where $i_t$ is investments per capita. Let us denote $\lambda_t(a_t, \ell_t)$ as the distribution of households over the state variables in period $t$ – that is, the mass of households in state $(a_t, \ell_t)$ in period $t$ is given by $\lambda_t(a_t, \ell_t)$.

The stationary equilibrium consists of the policy functions $g(a_t, \ell_t)$ and $c(a_t, \ell_t)$ that solve the household's problem and a stationary distribution $\lambda(a_t, \ell_t)$ for all $a_{t+1}$ and all $\ell_{t+1}$. Moreover, prices $r$ and $w$ solve the firm's problem, and the aggregate resource constraint $y = k + i$ is satisfied, where $y$ is aggregate per-capita output, $k$ aggregate per-capita capital, and $i$ aggregate per-capita investments.

## 3.2 Model Specification, Parameterization, and Computation

With model specification and parameterization we closely follow the original study by Aiyagari (1994). We assume that the period utility function is $u(c_t) = \frac{c_t^{1-\mu}-1}{1-\mu}$ with the relative risk aversion coefficient $\mu = 3$. The discount factor $\beta$ is set to 0.97 for one year period.

We model the labor endowment shocks with $s = 7$ states. By choosing $s = 7$ we follow Aiyagari's original estimations. The state space for $\ell$ is denoted by $\mathcal{L} = \{L_1, L_2, \ldots, L_s\}$. For discretizing a continuous stochastic process we use the Rouwenhorst method for the following AR(1) process:

$$\log(\ell_t) = \rho \log(\ell_{t-1}) + \sigma\sqrt{(1-\rho^2)}\varepsilon_t, \tag{8}$$

where $\varepsilon_t \sim N(0,1)$. For simplicity, we set the serial correlation parameter $\rho = 0$. In other words, we assume that the income of the population is distributed log-normally.

We use two different coefficients of variation $\sigma \in \{0.29, 0.3\}$. A jump in $\sigma$ represents an exogenous shock in inequality. We simulate our results first with $\sigma = 0.29$ and then change it to 0.3. After that we compare the results.[7]

Changing $\sigma$ from 0.29 to 0.3 has the desired two effects: an increase in the expected value and an increase in the variance of the labor endowment shocks. To be more precise, the expected values with different $\sigma$ are $\mathbb{E}(\ell|\sigma = 0.29) = 1.0428$ and $\mathbb{E}(\ell|\sigma = 0.3) = 1.0459$, whereas the variances are $(\ell|\sigma = 0.29) = 0.0938$ and $(\ell|\sigma = 0.3) = 0.1012$. That is, our generated inequality shock has relatively greater effect on the variance of the labor endowment rather than the expected value. The change is depicted in Figure 1.

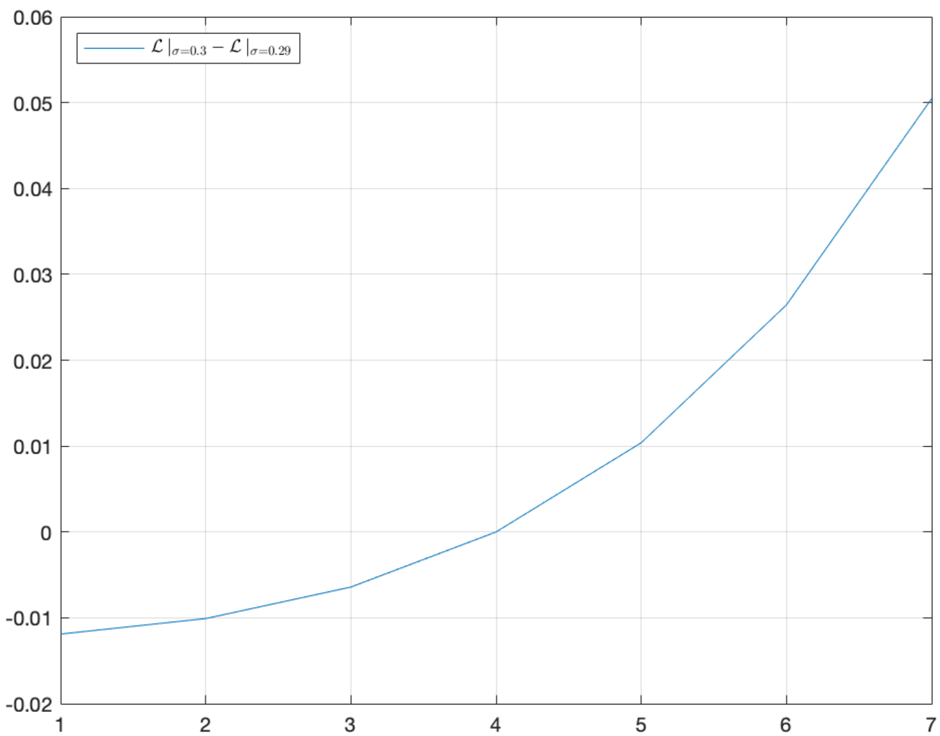



Figure 1: Change in labor endowment for states $1, 2, \ldots, 7$ after an inequality shock

[7]More description about the Markov chain approximation and discussion about the labor endowment shock can be found from Aiyagari (1994).

Our aim is to find out how the aggregate output and capital are affected by a change in $\sigma$ with different capital shares of income. In order to do so, we use the Cobb-Douglas production function $f(k_t, n_t)$ with the capital share parameter $\alpha$. For simplicity we normalize the labor force to unity and assume it constant over time. We hence need to study only the changes in the aggregate capital to get the reactions of the output as well. Results are reported for five different values of $\alpha \in \{0.1, 0.2, 0.3, 0.4, 0.5\}$. The capital depreciates at rate $\delta = 0.08$.

The asset grid is discrete $\mathcal{A} = \{A_1, A_2, \ldots, A_n\}$ with $A_1 \in \{0, 0.5, 1.0, 1.5, 2.0\}$, $A_n = 50$, and $n = 500$. We thus compare the results with five different credit constraints.

The stationary distribution $\lambda$ solves

$$\lambda_{t+1}(a_{t+1}, \ell_{t+1}) = \sum_{\ell_t \in \mathcal{L}} \sum_{\{a_t : a_{t+1} = g(a_t, \ell_t)\}} \lambda_t(a_t, \ell_t) P(\ell_t, \ell_{t+1}) \tag{9}$$

for all $a_{t+1} \in \mathcal{A}$ and all $\ell_{t+1} \in \mathcal{L}$, where $P(\ell_t, \ell_{t+1})$ is the transition probability from labor endowment $\ell_t$ to $\ell_{t+1}$ given by the Rouwenhorst method. The stocks of aggregate capital and consumption are given by

$$k = \sum_{i=1}^{n} \sum_{j=1}^{s} \lambda(A_i, L_j) g(A_i, L_j) \tag{10}$$

$$c = \sum_{i=1}^{n} \sum_{j=1}^{s} \lambda(A_i, L_j) c(A_i, L_j). \tag{11}$$

The firm's first-order condition gives us the (inverse) demand curve for capital r = $D_\alpha(k) = \alpha k^{\alpha-1} - \delta$. This is s decreasing function in capital and increasing in $\alpha$ since

$$\frac{\partial}{\partial k} D_\alpha(k) = \alpha(\alpha - 1)k^{\alpha-2} < 0 \qquad \text{for all } \alpha \in (0,1) \tag{12}$$

$$\frac{\partial}{\partial \alpha} D_\alpha(k) = k^{\alpha-1}(1 + \alpha \log(k)) > 0 \qquad \text{for all } \alpha \in (0,1) \text{ and } k > 1. \tag{13}$$

The inverse demand curve approach infinity as $k$ goes to zero, and tends to $-\delta$ as $k$ goes to

$\infty$.

The aggregate capital is given by $k = \sum_{i=1}^{n} \sum_{j=1}^{s} \lambda(A_i, L_j) g(A_i, L_j)$, where $g(A_i, L_j)$ is a function of $r$ and $w$ – so the optimal decision of tomorrow's capital depends on the real interest rate and the wage level. We write the (inverse) capital supply as $r = S_\alpha(k)$ which is given by the aggregate capital equation.[8] This is the same curve as Aiyagari's (1994) curve $\mathbb{E}a(r)$ given by the $\mathbb{E}a_w = \mathbb{E}\{g(a, \ell)\}$, where $\mathbb{E}\{\cdot\}$ denotes the expectation with respect to the stationary distribution. It can be shown that $\mathbb{E}a(r)$ is a continuous function of $r$ but not necessary monotone (see Bewley (1984) and Clarida (1990)). Moreover, $\mathbb{E}a(r)$ approaches to infinity as the interest rate goes towards the rate of time preference $\lambda$. That is, $S_\alpha(k)$ is a continuous function such that $\lim_{k\to\infty} S_\alpha(k) = \lambda$. In words, if the interest rate exceeds the rate of time preference, then the households would not consume at all and accumulate an infinite amount of assets which would explode the aggregate supply as well.

Aiyagari (1994) points out an important feature of $S_\alpha(k)$ for our purposes: $S_\alpha(k)$ is always lower under uncertainty than if earnings were certain. This is due to the borrowing constraint and the infinite-horizon maximization of households. However, and interestingly, the capital supply does not decrease monotonically everywhere with uncertainty. It might be the case that an increase in the variance of the labor endowment (an increase in the income uncertainty and so an increase in income inequality) decreases $S(k)$, but also makes it more steep. This can make the original and the shifted capital supply curves to intersect at some point. This can give a rise to the opposite reactions of equilibrium capital with different capital shares of income $\alpha$. This phenomenon is depicted in Figure 2. On the left-hand side figure a positive shock in the variance of income increases the equilibrium capital, and vice versa on the right-hand side figure.

Why and when this could be the case? First, since the households do precautionary savings, increasing the variance of the labor endowment increases the savings in each asset level. However, due to the increase in the expectations of the income, there is also a consumption

[8]Note that $S$ is also affected by $\alpha$ since $r$ and $w$ are functions of $\alpha$.

smoothing effect: in the aggregate level households consume more and invest less.

It turns out that with low interest rate the precautionary savings effect dominates the consumption smoothing effect. Savings yield less with low interest rate and the households must save relatively much for the bad times. An increase in uncertainty then makes the households even more precautionary. In this case the capital supply increases and consequently the equilibrium capital is greater after an inequality shock than before. This appears as a shift in the supply curve $S_\alpha(k)$ to the right in Figure 2.

As for high interest rates, the consumption smoothing effect dominates the precautionary motives. This is due to the fact that now the assets yield good returns and a lower increase in savings compensate easily the increased uncertainty. Then the increased expectations about the future income makes the households to consume more rather than save. Consequently, the aggregate capital supply decreases with high interest rates.

Putting these two stories together, an inequality shock shifts the capital supply curve to the left and makes it more inelastic. Since this has no impact on the capital demand, we observe different equilibrium outcomes with different production functions after an inequality shock.

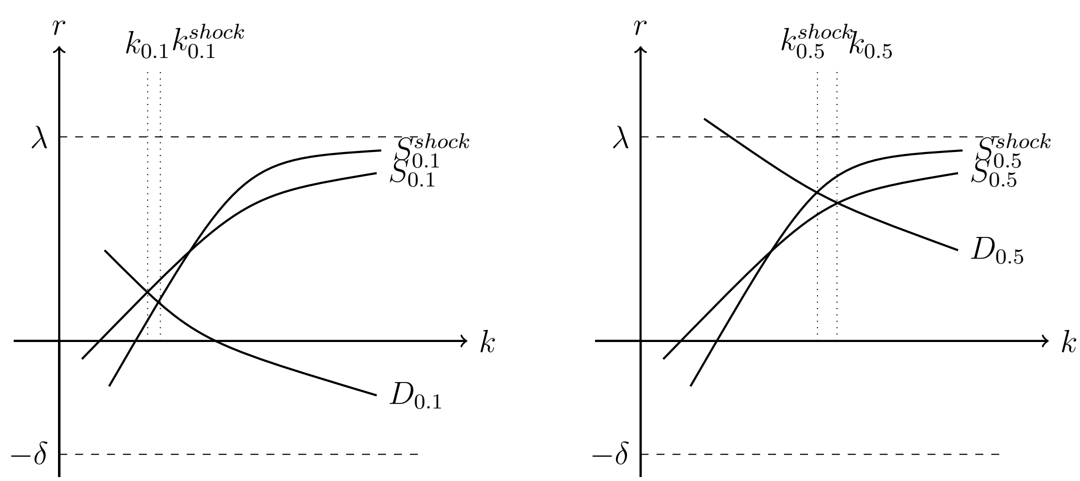



Figure 2: Equilibria in Capital Market with $\alpha \in \{0.1, 0.5\}$.

Consider first a case in which the capital share of income is high (e.g. $\alpha = 0.5$). Now the capital is efficient in production and the demand of it is high. Then a positive inequality shock has a negative effect on the equilibrium capital level since the consumption smoothing effect is dominant. However, with a small capital share of income (e.g. $\alpha = 0.1$) this effect is positive. This is due to the fact that the precautionary savings effects are dominating. This exact possible scenario is illustrated in Figure 2.

The aggregate output is given based on the aggregate capital by the production function as $y = k^{\alpha}$, and consequently, reacts to the same direction as capital. We simulate the effects of the inequality shock on the output. The results are given for five different credit constraints $A_1 \in \{0, 0.5, 1.0, 1.5, 2.0\}$.

Figure 3 depicts the results of simulations by showing the difference between the equilibrium output $(y)$ with $\sigma = 0.29$ and $\sigma = 0.30$. We observe that once we increase the credit constraint the negative change in output disappears. This is due to the fact that the greater the credit constraint, the weaker the consumption smoothing effect; the households cannot utilize the increased income in consumption because of the binding credit constraint. Consequently, the precautionary savings effect dominates. This results in a situation where a positive inequality shock has *always* a positive impact on output for all $\alpha \in \{0.1, 0.2, 0.3, 0.4, 0.5\}$.

The equilibrium outcomes with $\sigma \in \{0.29, 0.30\}$ are reported in Appendix A in Tables 2 and 3. From there we observe that the income Gini coefficient is 0.159 with $\sigma = 0.29$ and 0.165 with $\sigma = 0.3$. The wealth Gini coefficients increase in $\alpha$ and are greater than the income coefficients. For instance, with $\alpha = 0.5$ and $\sigma = 0.29$ the wealth Gini coefficient is 0.307, whereas with $\sigma = 0.29$ it is 0.311. The model is thus qualitatively consistent with the income and wealth distributions: the wealth distribution is more dispersed than the income distribution, and the Gini coefficient is significantly higher for wealth than for income. However, which is a well-known feature of Aiyagari (1994) model, it does not generate empirically plausible relative degrees of inequality.

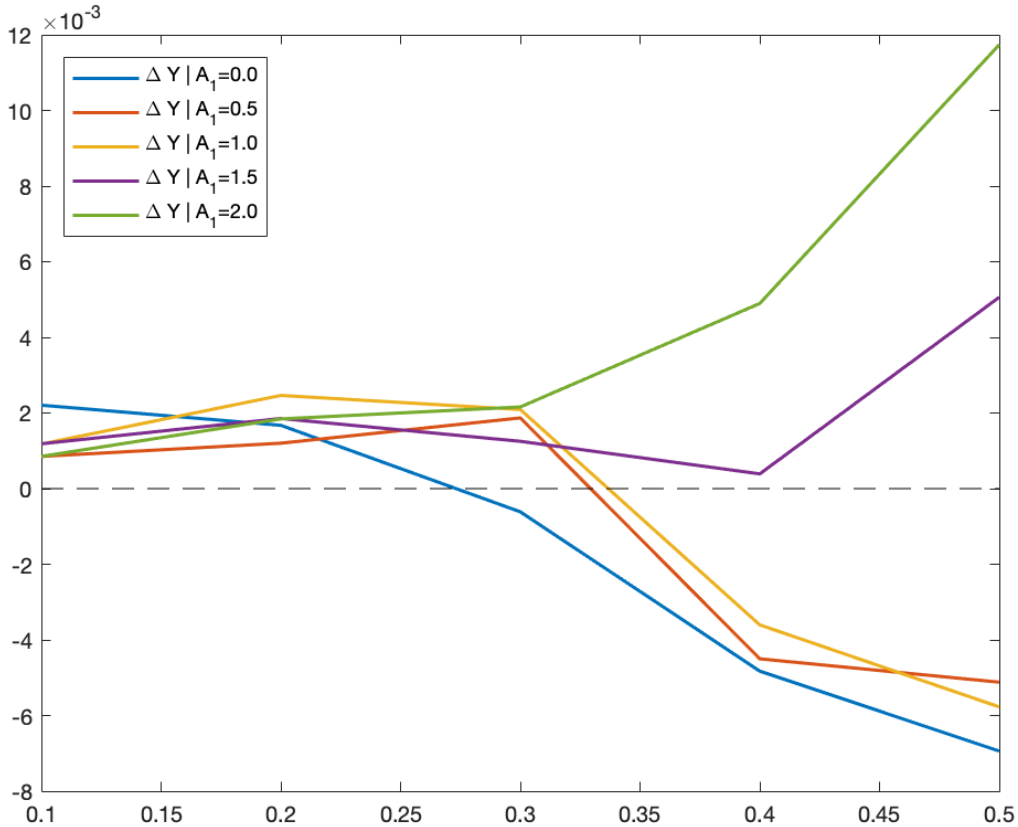



Figure 3: Simulated reaction of the aggregate output on a positive inequality shock with $\sigma \in \{0.29, 0.30\}$, $A_1 \in \{0, 0.5, 1.0, 1.5, 2.0\}$.

# 4 Empirical analysis

In this section, we present the results from our empirical analysis. Based on our theoretical model, we have two empirically testable hypotheses. First, we investigate whether the association between changes in income inequality and subsequent economic growth is i) positive when the capital share of total national income is low, and ii) negative when the capital share is high. Second, given that we find empirical support for the first hypothesis, we examine whether it fails to hold during eras of low financial development, i.e. when the credit constraint is binding, using the language of our theoretical model.

When drawing comparisons between our theoretical and empirical results, it is noteworthy that an Aiyagari (1994) type economy is a closed one while the countries in our sample have allowed for capital flows across national borders. However, domestic investment and savings tend to be highly correlated (see Feldstein and Horioka (1979) for seminal work on the topic), and consequently, we feel comfortable using our theoretical and empirical analyses as complements to one another.

Our analysis builds on a database compiled by Bengtsson and Waldenström (2018) and we adopt a standard panel growth regression approach (data and empirical approach presented in Section 4.1). To complement our baseline specification (reported in Section 4.2), we experiment with various alternative specifications to ensure the robustness of our findings (Section 4.3), and address the role of credit constraint (Section 4.4). As we discussed in the derivation of our theoretical model, we seek to explain how economic growth relates to income inequality conditional on the functional income distribution. Rather than examining the drivers of inequality, we make use of the variation in the distributional measures in a set-up that follows the previous empirical inequality-growth studies.

## 4.1 Data and empirical approach

For data on functional income distributions and income inequality, we resort to a study by Bengtsson and Waldenström (2018), who build on the work of Piketty and Zucman (2014). The authors not only provide lengthy time series for 21 countries but also examine the correlation between capital shares of total national income and the income shares of the top earners in a subset of 16 countries. Using the same data, Bengtsson et al. (2020) studied the association between capital shares and political and institutional changes. The data set, in which the coverage varies across countries (see Table 4, Appendix B), contains capital shares both gross and net of capital depreciation and the top income shares for the highest-earning top 10 %, top 1% and top 0.1 %.

We focus on a group of 13 developed countries instead of the 16 that Bengtsson and Waldenström (2018) analyzed. The reasons for this are, first, that the process of economic development in Argentina was substantially different from the other countries during the twentieth century and thus, we feel more comfortable pooling the data when Argentina is excluded. Second, for Ireland and Spain, the data coverage is remarkably worse than for the remaining 13 countries. Consequently, the countries included are Australia, Canada, Denmark, Finland, France, Germany, Japan, Netherlands, New Zealand, Norway, Sweden, the United Kingdom and the United States.

In our analysis, we prefer the capital shares net of capital depreciation over the gross shares. Bengtsson and Waldenström (2018) point out that even though the net share is the appropriate "who gets what" measure, the capital depreciation rates need to be estimated, which adds an additional layer of uncertainty to the data. We also experiment with the gross shares to ensure that the results are not driven by patterns in depreciation rates.

Another measurement issue is the estimation of labor income of self-employed workers, whose income is not decomposed into labor and capital compensation in national income accounts and is therefore not directly observable. Bengtsson and Waldenström (2018) assume that one third of the self-employed incomes are capital income while the rest is assigned to labor income, which has been a typical solution for the issue.[9]

Data on the income shares of total national income come from the World Inequality Database (previously the World Top Incomes Database). The data are constantly improving on both quality and coverage and are freely available online.[10] The top 1 % income shares outperform the top 10 % and the top 0.1 % in coverage and since the highest-earning percentile has been "the income bracket" in public debate and previous studies on income inequality, it rightfully earns its place as the preferred variable in this study. However, we also make use of the the top 10 % and the top 0.1 % to investigate the sensitivity of our results to alternative definitions of the top income shares. The income shares are calculated before taxes and transfers, and they are based on annual tax returns and the methods to construct the income shares emphasize long-run comparability. To our understanding, no other data source would enable us to better analyze the 13 countries in our sample over the twentieth century.

The use of the top income shares has some disadvantages. First, these data only focus on the right tail of the income distribution. However, Bengtsson and Waldenström (2018) found that population-wide measures – such as the Gini coefficient – have substantially worse country-time coverage over their sample period. The top income shares are also found to track the broader measures (Leigh, 2007), which suggests that the top income shares are useful in the absence of information on the full income distribution. Moreover, it is not evident that the Gini, for example, would be the "best measure of income inequality" as it places more weight in the middle of the distribution thus effectively undervaluing the variation in the tails. Second, income inequality before taxes and transfers is different from the dispos-

[9] Gollin (2002) finds that as the labor income of the self-employed was often treated as capital income, the variation in the labor income shares between rich and poor countries seemed to be an artifact of misleading statistical procedures. More careful approach on the self-employed workers' incomes results in labor shares ranging between 0.65 and 0.80, whereas the naïve shares lie between 0.05 and 0.80. In the US, the headline measure of the labor share has relied on the assumption of equal wages for self-employed and payroll-employed. However, the data on recent evolution between the wages of these two groups reveals that the assumption is violated and roughly one third of the fall in the labor shares can be attributed to the dubious baseline measure (Elsby et al., 2013).

[10] See `https://wid.world/`

able income inequality. As our consumption, savings and investments decisions are based on the income we actually get, disposable income shares would perhaps be more suitable – or at least offer a meaningful comparison to our data – when analyzing the consequences of inequality on economic activity. As above, the the measures that capture inequality in disposable income are not available for the same coverage as the data used in this study.

The data on per capita GDP come from the Maddison Project Dataset (Bolt et al., 2018). The time series stretch to the 19th century for many countries, and even to the Middle Ages for some, thus making it possible to evaluate economic activity in a cross-country basis over a very long run.

Following a standard convention in the previous literature, we focus on the growth of per capita GDP inside five-year non-overlapping windows. By doing so, we aim to (i) move away from a short-run scope influenced by business cycles; and (ii) mitigate the issues of missing observations and noisiness stemming from potential measurement errors in the top income share and capital share time series. The estimation sample consists of 230 total observations and includes 13–21 growth windows per country. The detailed composition is reported in Table 5 (Appendix B).

Figures 4 and 5 show the evolutions of the income shares of the highest-earning percentile and capital shares when the data are averaged over the five-year windows. The variables are expressed in decimals: the sample mean for top 1 % income share, 0.104, implies that on average the highest-earning percentile received 10.4 % of the total pre-tax & pre-transfer national income; and the sample mean for capital share, 0.261, indicates that the capital income on average constituted 26.1 % of the total national income, while 73.9 % was labor income.

Both figures depict a U-shape, which is more distinctive for the top income shares. The relative incomes of the best-paid individuals declined in all countries between the early twentieth century and 1950, whereas since the 1980s, countries such as Canada, the United Kingdom and especially the United States have experienced substantial increases in the top income shares. Among the rest of the countries, the shares have remained at low levels or risen less dramatically. Although there is a noticeable dip in the capital shares roughly between 1960 and 1980 in many countries, the evolutions of functional income distribution show more cross-country heterogeneity than the ones of personal income distribution. Thus, categorization of countries or identifying common time trends is not as evident as for the top income shares.

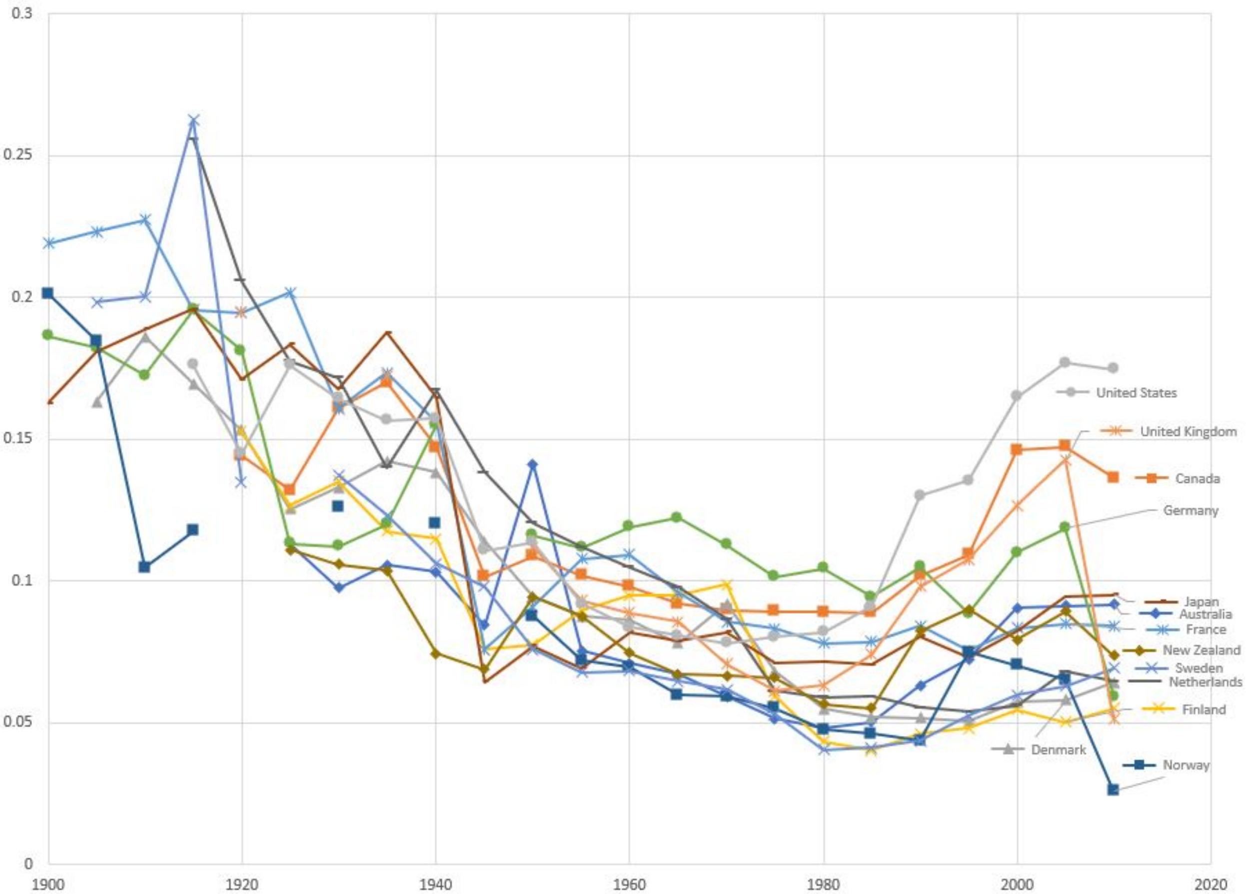



Figure 4: Top 1 % income share, five-year non-overlapping windows

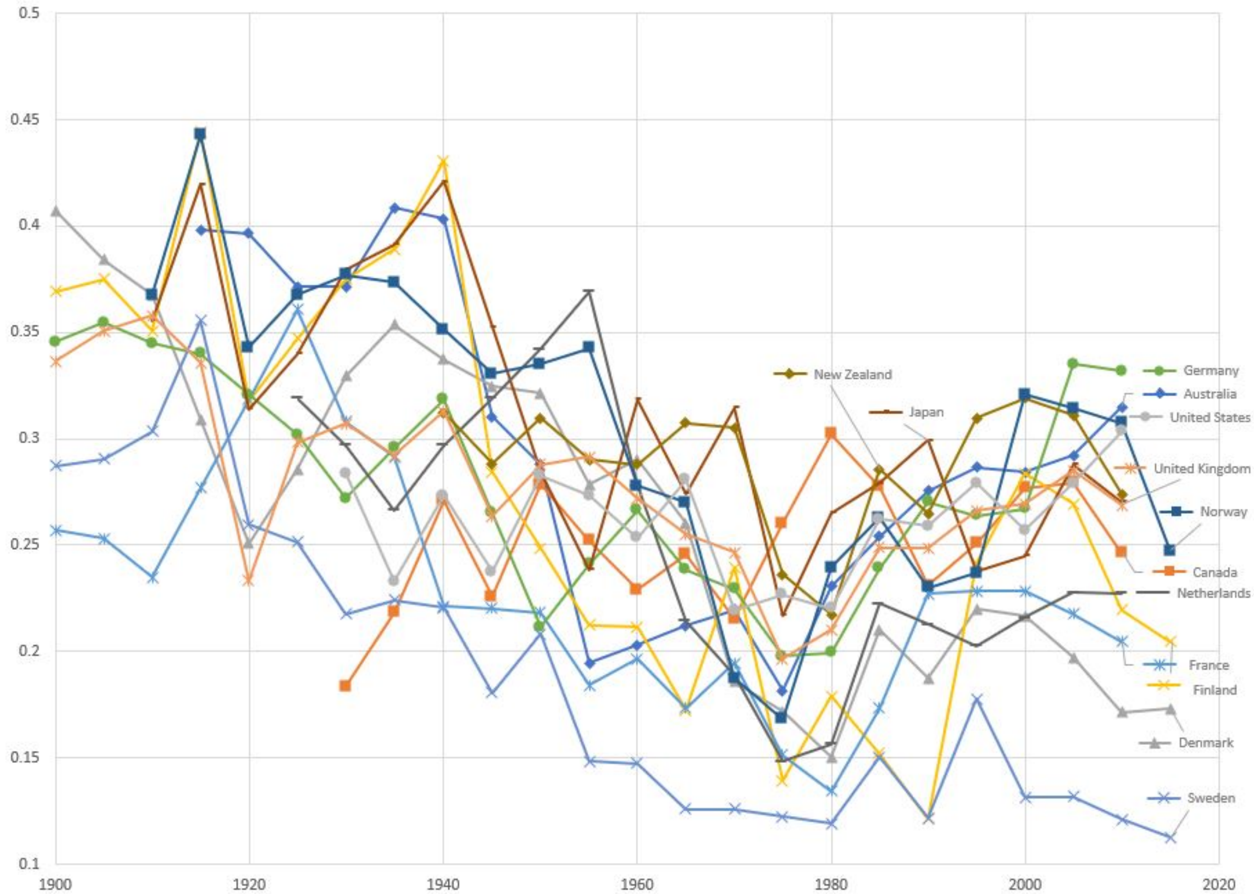



Figure 5: Capital share, five-year non-overlapping windows

The descriptive statistics on growth of per capita GDP and the distributional measures are summarized in Table 6 (Appendix B). Our sample countries experienced the highest average rates of economic growth during the decades after the Second World War (1950–1980 in Table 6). During this 30-year period, none of the economies we analyze shrunk during any five-year growth window. The smallest and largest window-to-window growth rates were experienced during the turmoil of the first of half of the twentieth century.[11] For the distributional measures, Table 6 depicts similar evolutions as Figures 4 and 5. Interestingly, in average terms, the top 1 % shares were at lower levels during the period 1985–2010 than during the post-WWII decades despite the recent substantial increases in the top income shares in some of the countries in our sample (namely Canada, the UK and the US).

[11]Note that we investigated also the sensitivity of our results to these extreme values by dropping them from the analysis as one of our robustness checks.

As the first step to examine the relationship between economic growth, top income shares and capital shares, we plot the observations in a three-dimensional illustration (Figure 8, Appendix B). We also fit a regression plane to the data based an a pooled least squares regression, where the growth of per capita GDP is regressed on contemporaneous income share of the top 1 % income and capital shares. Clearly, the simple correlation between economic growth and top 1 % income share is negative as the plane is down-ward sloping towards high values of top income share. The most obvious source of bias is that poorer countries tend to be more unequal and simultaneously, due to growth convergence, have higher growth rates of per capita GDP. The plane also tilts slightly towards high values of capital share indicating that the contemporaneous correlation between growth and capital share is modestly negative.

Our main results are based on the following panel growth regressions. Namely, we regress per capita growth on income inequality ($Top1$) and functional income distribution ($\alpha$, we adopt the notation from the theoretical model):

$$\begin{aligned}\frac{1}{4}(lnY_{i,t+4} - lnY_{i,t}) = \beta_1(\frac{1}{5}\sum_{j=0}^{4} lnY_{i,t-5+j}) + \beta_2(\frac{1}{5}\sum_{j=0}^{4} Top1_{i,t-5+j}) \\ + \beta_3(\frac{1}{5}\sum_{j=0}^{4} \alpha_{i,t-5+j}) + \beta_4(\frac{1}{5}\sum_{j=0}^{4}(Top1 \times \alpha)_{i,t-5+j}) + \omega_i + \eta_t + \varepsilon_{i,t},\end{aligned} \tag{14}$$

where $\omega_i$ and $\eta_t$ are the vectors of fixed country and year effects and $\varepsilon_{i,t}$ is the overall error term. $Y_{i,t}$ stands for the expenditure-side based measure of real per capita GDP in country $i$ in year $t$. The inclusion of country fixed effects is motivated by cross-country comparability of the adopted data, namely, Bengtsson and Waldenström (2018) state that "most of the time series are consistent within countries, whereas the comparability across countries is lower". Thus, the empirical approach effectively relies on the variation within countries. By including the year fixed effects, we aim to control for omitted variable bias stemming from unobserved variables that have evolved over the sample period but that have been constant across countries, such as shared trends in educational attainment, openness to trade and technological change.

The logarithmic difference in $Y_{i,t}$ between two time periods corresponds to growth rate, which is annualised by $\frac{1}{4}$ when observations that are five years apart are considered. The income share of the highest-earning percentile and capital share are observed during the preceding five-year window, as is also the level of economic development. As less-developed countries tend to have higher growth rates than the developed ones, we expect that the coefficient for the "convergence term" ($\beta_1$) is negative. Consequently, the statistical specification of equation (14) allows us to examine whether the association between inequality and growth is dependent on the level of capital share when we control for country and year fixed effects, growth convergence and the potential direct role that functional income distribution plays in the growth process.

We have chosen the parsimonious growth regression, equation (14), for three reasons. First, we are unsure what other growth determinants to include in our panel regression as we do not know what the "true" regression is. As Sala-i Martin (1997) states, "A good theorist [...] could make almost any variable look like an important theoretical determinant of the rate of economic growth". Second, the exclusion of additional control variables is not likely to deteriorate the credibility of our results. We can capture a partial correlation rather than a causal estimate irrespective of whether we include some of the dozens of suggested growth determinants. Rather, we interpret the empirical results in terms of the model presented in Section 3. Third, high-quality data covering the 13 countries of the study on the potential control variables over the twentieth century are difficult to come by.

Nevertheless, to ensure that our results are not sensitive to the exclusion of widely-used control variables in growth regressions, we experiment with alternative specifications. If we include only population growth (Bolt et al., 2018) and educational attainment (Barro and Lee, 2013), we do not lose any observations. The data on investment per GDP (Jordà et al., 2017) do not cover New Zealand and five individual windows from other countries, and consequently, the number of observations drops from 230 to 212. Proceeding sequentially, the inclusion of public debt per GDP (Jordà et al., 2017) and the sum of exports and imports per GDP (Fouquin et al., 2016), reduces the sample to 199 observations.

## 4.2 Main results

In Table 1, we introduce the explanatory variables of equation (14) sequentially. In all models, we include the level of economic development, a constant term and both country and year fixed effects. The first regression includes the log of per capita GDP inside the previous five-year period as the only explanatory variable for the growth of per capita GDP inside a five-year window (column (1)). As expected, this estimate is negative in all specifications. Column (2) presents the simple inequality-growth regression, column (3) reports the association between functional income distribution and growth, column (4) has both the top 1 % income share and capital share while column (5) matches equation (14) as it introduces the interaction term $Top1 \times \alpha$.

Columns (2)–(4) show that the associations between income inequality and growth and capital shares and growth are very weak in a linear form. The result of column (2) accords with Andrews et al. (2011), who found no systematic relationship between the top income shares and growth over the twentieth century. Allowing for interaction between the income share of the highest-earning percentile and capital share (column (5)) shows evidence for a richer story. The coefficients are individually and jointly statistically significant suggesting that the association between growth and top 1 % income share is positive under low capital share. Compatible with the predictions of our theoretical analysis, the positive association becomes smaller as capital share increases and turns negative after capital share reaches a value 0.281 (28.1 %)

To illustrate the magnitude of our main finding (Table 1, column (5)), let us consider capital share at the first and third quartile in our sample, 0.217 and 0.302, respectively.[12]

[12]To clarify, 25 % of the sample values are below 0.217, whereas 25 % of the sample values are above

Table 1: Top 1 % income share, capital share and the subsequent growth of per capita GDP

Fixed effects panel regression, column (5) corresponds to equation (14). Growth of per capita GDP inside a five-year non-overlapping window as the dependent variable, explanatory variables observed during the previous window. Year fixed effects included. Null hypotheses for tests of joint significance: the coefficients are not jointly significant.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Initial $lnY$ ($\beta_1$) | -0.0359*** | -0.0360*** | -0.0371*** | -0.0370*** | -0.0387*** |
| | (0.0080) | (0.0079) | (0.0087) | (0.0085) | (0.0064) |
| $Top1$ ($\beta_2$) | | -0.0217 | | 0.0112 | 0.6032** |
| | | (0.1044) | | (0.1101) | (0.2073) |
| $\alpha$ ($\beta_3$) | | | -0.0797* | -0.0808* | 0.1554 |
| | | | (0.0402) | (0.0429) | (0.1034) |
| $Top1 \times \alpha$ ($\beta_4$) | | | | | -2.1448** |
| | | | | | (0.9307) |
| Constant | 0.3291*** | 0.3334*** | 0.3641*** | 0.3623*** | 0.3169*** |
| | (0.0684) | (0.0654) | (0.0803) | (0.0747) | (0.0629) |
| Joint significance of $Top1$ and $\alpha$ (p-value) | | | | 0.1818 | |
| Joint significance of $Top1$ and $Top1 \times \alpha$ (p-value) | | | | | 0.0233 |
| Joint significance of $\alpha$ and $Top1 \times \alpha$ (p-value) | | | | | 0.0390 |
| Joint significance of $Top1$, $\alpha$ and $Top1 \times \alpha$ (p-value) | | | | | 0.0488 |
| R-squared | 0.3387 | 0.3390 | 0.3521 | 0.3521 | 0.3869 |
| Observations | 230 | 230 | 230 | 230 | 230 |
| Number of countries | 13 | 13 | 13 | 13 | 13 |

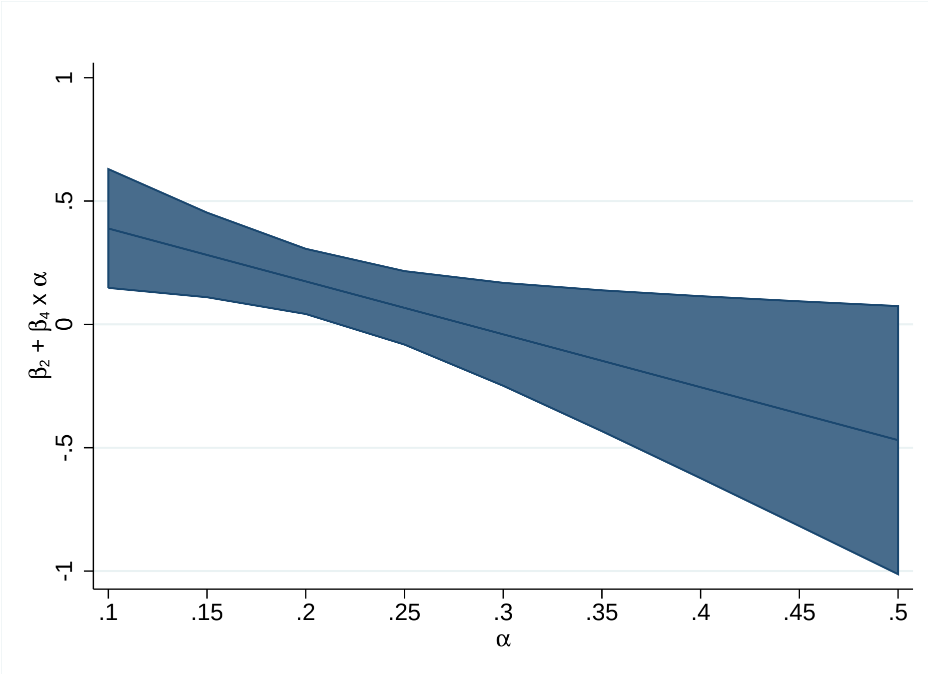
Robust standard errors in parantheses. *, ** and *** indicate statistical significance at 10 %, 5 % and 1 % levels, respectively

At the first quartile, one percentage point (pp) increase in the top 1 % income share during a given five-year period is associated with 0.14 pp higher annual growth of per capita GDP during the following five-year window. At the third quartile, the same increase in the top 1 % share is associated with 0.04 pp lower annual economic growth. Using a standard deviation change in the top 1 % (0.043 or 4.3 % as a percentage share) corresponds to 0.59 pp higher annual growth at the first quartile and 0.19 pp lower annual growth at the third quartile. Given that the average annual growth rate in our sample over the full period was roughly 2 %, the empirical association we discover is sizable.

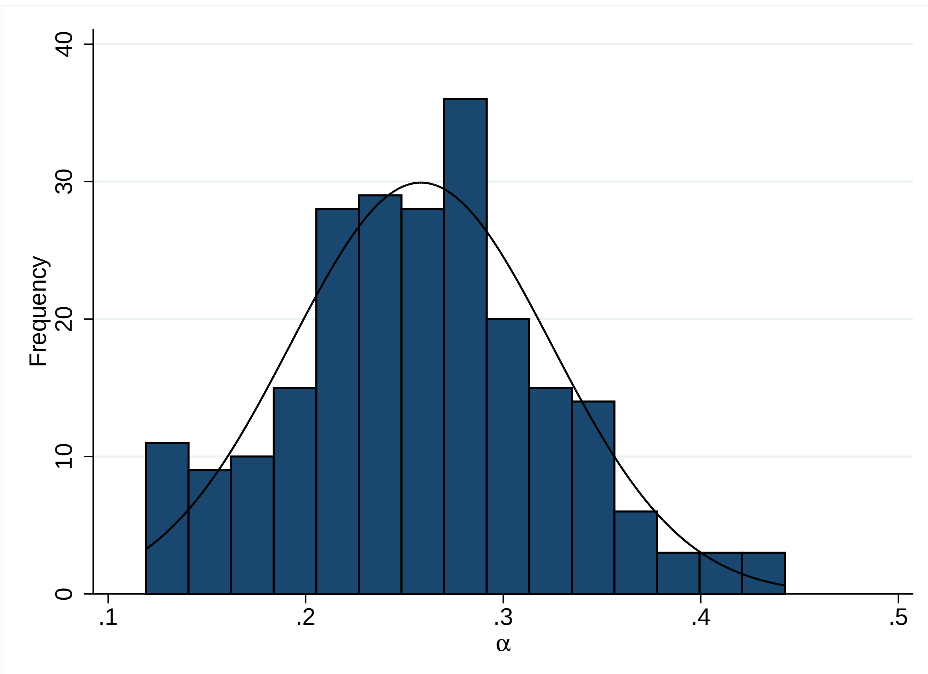
Although Table 1 suggests that the association between the top income shares and subsequent growth of per capita GDP depends on how total national income is divided between capital and labor, the result is difficult to interpret in terms of different capital share values. To improve on the interpretation, we introduce a graphical illustration, where the reduced-form estimate for the top 1 % income share on growth ($\beta_2 + \beta_4 \times \alpha$) is on the vertical axis and values of the capital share ($\alpha$) are on the horizontal axis (Figure 6a). In addition to the point estimate, 95 % confidence interval is included. This enables us to draw statistical inference on the interactive part of our specification far better than using regression tables. Furthermore, as the distribution of the conditioning variable is essential for the interpretation, we include a histogram for the sample values of capital share below the interaction plot (Figure 6b).

The interaction plot illustrates the main findings of Table 1, column (5): a down-ward sloping profile emerges as a function of $\beta_2$, $\beta_4$ and $\alpha$. Moreover, the association between the top 1 % income share and growth is positive and statistically significant under low values of capital shares. As the histogram shows, the results are meaningful in terms of sample values. The point estimate line crosses zero (0.281) remarkably close to the sample mean of capital share (0.261) and roughly one quarter of the capital share values are below the cut-off, where the lower bound of the confidence interval starts to take positive values in Figure 6a.

0.302.




(a) The association between growth of per capita GDP and top 1 % income share conditional on capital share (point estimate and 95 % confidence interval), $\beta_2$ and $\beta_4$ correspond to equation (14)




(b) Distribution of capital share in the estimation sample

Figure 6: Top 1 % income share, capital share and the subsequent growth of per capita GDP

The main empirical finding, i.e. the down-ward sloping line in Figure 6a, is compatible with the theoretical analysis of Section 3. Thus, we have shown the conditionality of the inequality-growth nexus to functional income distribution i) in a simple conceptual framework of capital market equilibria, ii) by simulating our theoretical model, and iii) empirically. It is worth emphasizing that i) and ii) stem from the seminal study by Aiyagari (1994): we simply adopt a novel perspective to the model in our analysis.

More precisely, the link between Figure 6a and the theoretical predictions holds when the credit constraint is small, i.e. when $A_1$ is equal to or smaller than 1.0. In words while still in terms of the theoretical predictions, the credit constraint seems not to have been excessively binding when we pool the data across the 13 countries over the twentieth century. We acknowledge that the empirical counterpart to the credit constraint of our theoretical model was not constant over the sample. Thus, although data that correspond to the credit constraint of the theoretical model are difficult to come by for our sample period, below in Section 4.4 we do our best to investigate how variation in the credit constraint, i.e. financial development, affects our empirical results. We believe that this is important since our theoretical results stress the importance of parameter $A_1$.

## 4.3 Robustness

Next, we estimate a number of different econometric specifications to verify the robustness of our results. These analyses are reported in Appendix C via interaction plots in a similar spirit to Figure 6a.

**Potential dependency to the level of inequality rather than to capital income share.** The linkages between functional and personal income distributions have been widely-studied (see Section 2), and previous studies clearly indicate that capital shares and top income shares tend to move together over time. Thus, our first robustness check relates to the notion that perhaps we are capturing the dependency of the inequality-growth relationship to the level of total income inequality rather than to the division of income between capital and labor. We investigate this by introducing the following panel regression:

$$\frac{1}{4}(lnY_{i,t+4} - lnY_{i,t}) = \beta_1(\frac{1}{5}\sum_{j=0}^{4} lnY_{i,t-5+j}) + \beta_2(\frac{1}{5}\sum_{j=0}^{4} Top1_{i,t-5+j}) \\ + \beta_3(\frac{1}{5}\sum_{j=0}^{4} Top1^2_{i,t-5+j}) + \omega_i + \eta_t + \varepsilon_{i,t}, \quad (15)$$

where we let the association between the top 1 % total income share and growth of per capita GDP to depend on the level of top 1 % share. Otherwise, the notation follows equation (14) and there are no changes in the sample. Figure 9 clearly shows that our main findings cannot be explained by dependency to the level of inequality. This result further strengthens our main finding about the role of functional income distribution for the inequality-growth relationship.

**The inclusion of additional variables as controls.** The inclusion of control variables is not straightforward as, with the distributional measures already narrowing the coverage, we have a small sample for our empirical analysis. Consequently, we prefer not to narrow the data and present results corresponding to equation (14), Table 1 and Figure 6a as our main findings. Yet, Figure 10 shows that our finding remains when we include a set of additional variables, for which we have data for, into our regression.[13]

[13]For the model that corresponds to Figure 10a, the data on population growth is obtained from the Maddison project dataset (Bolt et al., 2018) and it is measured as an average over the preceding growth window, whereas the data source for average total years of education contains observations for every five years (Barro and Lee, 2013), and consequently, educational attainment is observed at $t-5$. For Figure 10b, we have the two previous variables and investment per GDP ratio (measured as an average over the preceding growth window) taken from Jordà et al. (2017). Finally, for Figure 10b, we further introduce two additional controls, which are both measured as averages over the preceding growth window: public debt to GDP ratio is taken from Jordà et al. (2017) while the data on the ratio of trade to GDP come from Fouquin et al. (2016). The underlying model for Figure 10a relies on the same sample as our previous analysis (230 total observations), whereas the models for Figures 10b and 10c are estimated using 212 and 199 observations, respectively.

**Excluding the extreme growth rates of per capita GDP.** Our sample period includes the turmoil of the early twentieth century, the Great Depression and the two World Wars. These periods were characterized by volatile growth rates of per capita GDP even if we focus on five-year non-overlapping windows (Table 6), which might obscure our results. To evaluate whether our results are driven by this exceptional variation, we re-estimate our model by excluding these extreme growth rates (bottom and top 5 % of the observed growth rates are dropped for Figure 11a, whereas Figure 11b excludes the 10 % tails). The slopes of the profiles now become slightly more gradual than the slope in Figure 6a and the confidence intervals are much tighter around the point estimate lines. We conclude that the main result is not sensitive to whether we include the extreme observations or not.

**Top 10 % and top 0.1 %.** Our next robustness check utilizes alternative top income shares. The data compiled by Bengtsson and Waldenström (2018) enables us to use the top decile and top 0.1 percentile in addition to the top percentile with the costs of using only slightly smaller sample size. For top 10 %, we lose 13 observations from Finland and some from Australia, Canada, Germany and Japan. For top 0.1 %, we lose all observations from Finland and some from Germany, Netherlands, New Zealand, Norway and the United Kingdom. To ensure a meaningful comparison, we use a sample of 12 countries & 187 observations that includes information of all three measures. Moreover, to facilitate comparison, we use log transformations of the top income shares.

Figure 12 shows that the main result is qualitatively similar between the different definitions for top income shares. However, the slopes of the profiles differ: it is relatively steep for top 10 % (Figure 12a), moderate for top 1 % (12b) and gradual for top 0.1 % (12c). Thus, it seems that the magnitude of the mechanism uncovered in this study depends on how close we zoom to the right tail of the income distribution.

The role that the division of income between capital and labor plays on the growth-consequences of inequality seems to loose its importance at the very high-end of the income distribution. In other words, functional income distribution becomes less important for the inequality-growth relationship. In terms of our theoretical analysis, the mechanism driven by precautionary saving motives decreases the higher we zoom into the income distribution.

**Capital shares gross of capital depreciation.** We also have information on capital shares gross of capital depreciation (Bengtsson and Waldenström, 2018). The sample remains identical to the main analysis (Table 1 and Figure 6), and the similarity between Figures 6a and 13a shows that our findings are not sensitive to how capital depreciation is addressed.

**Addressing dependency to both the extent of inequality and capital share.** Next, we examine the sensitivity of our results to the extent of inequality by allowing for different coefficients at the top ($t50$) and bottom half ($b50$) of the distribution for the top 1 % income share:

$$\begin{aligned}\frac{1}{4}(lnY_{i,t+4} - lnY_{i,t}) = \beta_1(\frac{1}{5}\sum_{j=0}^{4} Y_{i,t-5+j}) + \beta_2^{t50}(\frac{1}{5}\sum_{j=0}^{4} Top1^{t50}_{i,t-5+j}) \\ + \beta_2^{b50}(\frac{1}{5}\sum_{j=0}^{4} Top1^{b50}_{i,t-5+j}) + \beta_3(\frac{1}{5}\sum_{j=0}^{4} \alpha_{i,t-5+j}) + \beta_4^{t50}(\frac{1}{5}\sum_{j=0}^{4} (Top1^{t50} \times \alpha)_{i,t-5+j}) \quad (16) \\ + \beta_4^{b50}(\frac{1}{5}\sum_{j=0}^{4} (Top1^{b50} \times \alpha)_{i,t-5+j}) + \omega_i + \eta_t + \varepsilon_{i,t},\end{aligned}$$

where the notation follows equation (14) again. In all specifications, we fail to reject the null hypothesis of equality of coefficients between the top-half and bottom-half data. The interaction plots (Figure 14) also show that our main results are independent of the top-bottom distinction.

**Average annual growth instead of annualized growth.** In equation (14), the growth of per capita GDP is defined as the growth from year $t$ to year $t + 4$ after which the growth rate is annualized. To examine the sensitivity of our results to the definition of growth rates, we replicate our analysis by using average annual growth rates inside the corresponding five-year window. Since we do not wish to mix information from different windows[14], we use annual rates from $t+1$ to $t+4$. The resulting growth rates are unsurprisingly more volatile than the preferred ones. Despite the added variation, our main findings hold. In fact, the confidence intervals around the familiar down-ward sloping profiles become slightly narrower especially for high values of $\alpha$ (Figure 15).

**Different panel estimators.** In addition to the fixed effects estimator, we also consider two other standard panel estimators, the random effects (RE) and the pooled OLS (POLS). RE and POLS do not control for the time invariant country-specific unobserved characteristics. Consequently, they make use of variation both in time and between countries. Figure 16 verifies our original results. Moreover, we also estimated the FE, RE and POLS models without the year dummies and / or the linear capital share term ($\beta_3(\frac{1}{5}\sum_{j=0}^{4}\alpha_{i,t-5+j})$), and the main finding holds.

Nowadays, the reduced-form panel studies typically rely on GMM estimates, which are used to control for the bias in dynamic panels with relatively few observations (Nickell bias), reverse causality and omitted variables. For our panel, this class of estimators are ill-suited as they tend to run into over-identification issues when the number of countries is small relative to the number of time periods. Moreover, the dynamic panel bias diminishes with the number of time periods.

## 4.4 The role of financial development

Our baseline empirical model, equation (14), enables us to trace how accounting for functional income distribution affects the inequality-growth relationship. Yet, our theoretical analysis not only emphasizes the role of capital income share, $\alpha$, but also shows that the results are conditional on the credit constraint, $A_1$. Ideally, we would investigate the role of

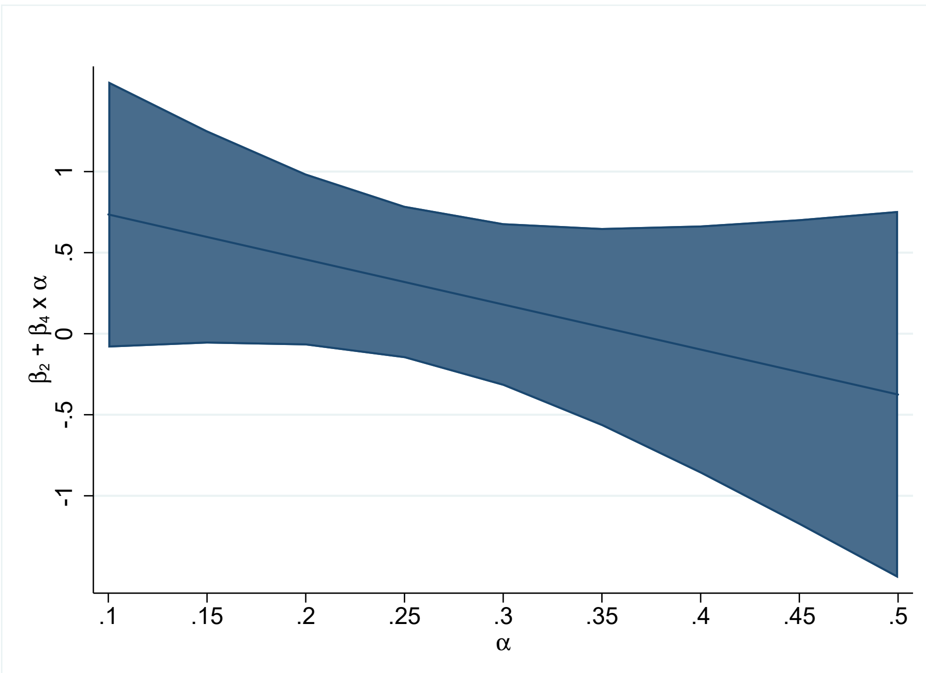
[14] The growth rate at year $t$ would not be independent of $t-1$ because the rate is calculated as $lnY_{i,t} - lnY_{i,t-1}$.

credit constraint by augmenting our empirical specification with a proxy for credit constraint as a threshold variable, or more simply, by dividing our sample into eras or country groups characterized by "more binding" and "less binding" credit constraints. Neither of the alternatives are easy to conduct due to limited data on the measures of financial development, which are typically used as empirical counterparts to a theoretical concept of a credit constraint, due to limited sample size of our analysis in general, and due to non-homogeneous timing of changes in financial conditions.

In the absence of data that would match the coverage of the time series compiled by Bengtsson and Waldenström (2018), we rely on lower frequency data from the study by Rajan and Zingales (2003), who analyze the determinants of financial development over the twentieth century. The pieces of information relevant to our study are gathered in Table 7 and Figure 17 in Appendix D. Most measures show that financial development was at a low level during the decades after the Second World War until the 1980s among the countries in our sample. Rajan and Zingales (2003) summarize the patterns by stating that "countries were more financially developed in 1913 than in 1980 and only recently have they surpassed their 1913 levels.". Kuvshinov and Zimmermann (2019), who document that stock market capitalization per GDP ratio was relatively stable from 1870 to the early 1980s and then tripled during the 1980s and 1990s, label the recent structural shift as the big bang.

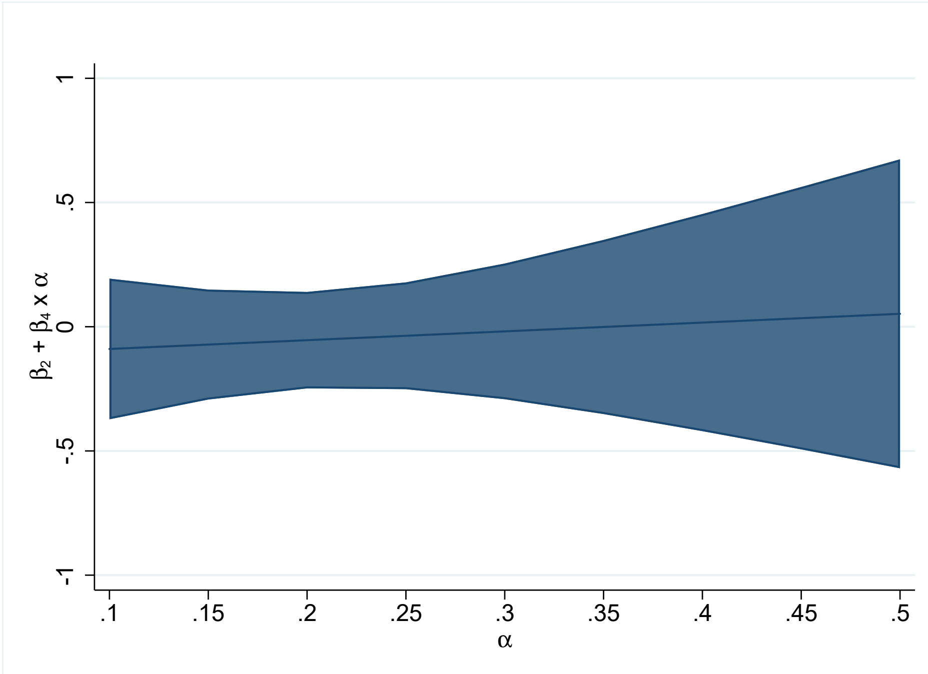
The evolutions summarized above lay the groundwork for our empirical analysis on the role of credit constraint. We split our sample into three periods, and characterize 1900–1945 and 1985–2010 as periods of high financial development, and 1950–1980 as a period of low financial development. As high financial development corresponds to low credit constraint, and vice versa, we turn our focus to the theoretical predictions of Section 3. First, we expect that the down-ward sloping profile – familiar from Figure 3 with low credit constraint and Figure 6a – will be particularly distinguishable for 1900–1945 and 1985–2010. For 1950–1980, on the contrary, we expect not to find a down-ward sloping profile between the inequality-growth association and capital share.

Similarly to the full sample (Figure 6a) pooling data over periods 1900–1945 and 1985–2010 (Figures 7a and 7c) displays that the association between the top income shares and growth of per capita GDP is a decreasing function of capital share, $\alpha$. However, when we set our focus on the period 1950-1980, the profile is flat and indicates that the relationship between the top income shares and growth is statistically insignificant for all values of $\alpha$ (Figure 7b). These findings correspond to the patterns described by Rajan and Zingales (2003), and, to our interpretation guided by our theoretical analysis, stem from loose credit constraint during the first half of the twentieth century and between 1985 and 2010, whereas 1950-1980 was characterized by a more binding constraint.

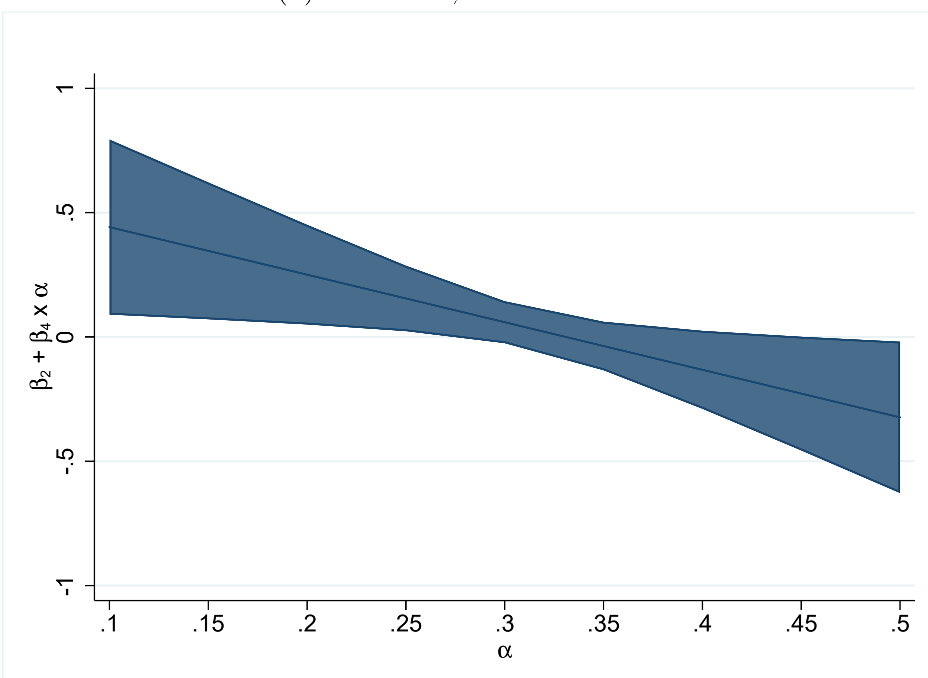



(a) 1900-1945, 67 observations

Figure 7: The association between growth of per capita GDP and top 1 % income share conditional on capital share (point estimate and 95 % confidence interval), $\beta_2$ and $\beta_4$ correspond to equation (14)




(b) 1950-1980, 88 observations




(c) 1985-2010, 75 observations

Figure 7: The association between growth of per capita GDP and top 1 % income share conditional on capital share (point estimate and 95 % confidence interval), $\beta_2$ and $\beta_4$ correspond to equation (14)

Although Figures 7a and 7c look similar in terms of the down-ward sloping profile, there is a clear difference in the confidence intervals between the figures: the estimated association is much more precise in 1985-2010. This pattern may stem from improvements in the quality of data, or alternatively, it may represent the link between personal and functional income distributions becoming more similar across countries, and consequently, the relationship between our two distributional measures and growth can be estimated more precisely.

# 5 Conclusion

We have revealed that the division of income between capital and labor crucially affects the conclusions that we draw on how changes in income inequality are associated with subsequent growth of per capita GDP. We demonstrate this dependency both empirically and theoretically. Furthermore, we show how the interplay between the distribution of income – both personal and functional – and economic growth appears when we account for financial frictions.

Our empirical analysis relies on historical data on GDP, the capital share of total national income and the top 1 % share of total national income. Constrained by data availability, we pool data from 13 developed countries, and following previous studies on the topic, we focus on five-year intervals. Using standard panel estimation techniques, we show that an increase in top 1 % income share is associated with higher subsequent growth of per capita GDP when capital share is low. Alternatively, under high capital share, the association between inequality and growth is negative. Our findings remained robust with respect to several tests: we included additional control variables, accounted for the level of income inequality, capital depreciation and different definitions of growth rates, excluded extreme observations, considered top 10 % and top 0.1 % shares in addition to the primarily used top 1 % and considered different panel estimation techniques.

To accompany our novel empirical finding, we make use of an established theoretical framework to demonstrate how personal and functional income distributions are connected with the accumulation of physical capital and economic growth. Both computational and capital market equilibrium analyses align with the empirical evidence, given that financial frictions are not excessive. The role of financial conditions arises from the data, too, as the inequality-growth relationship depends on the capital share during eras of high financial development, whereas this dependency is not present in the data under low financial development.

As our measure of income inequality focuses on the right tail of the income distribution, a complementary explanation for the observed empirical regularity may lie in the composition of income among the top earners. Investigating this possibility calls for more nuanced data and a different conceptual framework – both of which are beyond the scope of this study.

Our results should not be over-interpreted in terms of individual countries, forecasting or causality, and consequently, are not directly applicable for policy purposes. Instead, we stress the importance of our study in terms of incorporating functional income distribution into the extensive existing literature on the link between personal income distribution and overall economic activity.

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# Appendix

## A Theoretical Equilibrium Outcomes

Table 2: Equilibrium outcomes with $\sigma = 0.29$, $\rho = 0$, and $A_1 = 0$.

| y | k | c | i | n | r | w | s | $\alpha$ | $gini_{inc}$ | $gini_w$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.0317 | 1.3665 | 0.92092 | 0.1108 | 1 | -0.0055069 | 0.92993 | 0.10739 | 0.1 | 0.15883 | 0.22978 |
| 1.1908 | 2.3948 | 0.99806 | 0.19279 | 1 | 0.018831 | 0.95417 | 0.16189 | 0.2 | 0.15883 | 0.24117 |
| 1.5524 | 4.332 | 1.2056 | 0.34682 | 1 | 0.027426 | 1.087 | 0.22341 | 0.3 | 0.15883 | 0.24483 |
| 2.3868 | 8.8016 | 1.6823 | 0.70452 | 1 | 0.028412 | 1.4326 | 0.29517 | 0.4 | 0.15883 | 0.28908 |
| 4.5504 | 20.7063 | 2.8927 | 1.6577 | 1 | 0.029799 | 2.2769 | 0.3643 | 0.5 | 0.15883 | 0.30774 |

Table 3: Equilibrium outcomes with $\sigma = 0.30$, $\rho = 0$, and $A_1 = 0$.

| y | k | c | i | n | r | w | s | $\alpha$ | $gini_{inc}$ | $gini_w$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.0339 | 1.396 | 0.92091 | 0.11301 | 1 | -0.0068116 | 0.93176 | 0.10931 | 0.1 | 0.16421 | 0.23077 |
| 1.1925 | 2.4117 | 0.99846 | 0.19406 | 1 | 0.01832 | 0.9554 | 0.16273 | 0.2 | 0.16421 | 0.24024 |
| 1.5518 | 4.3263 | 1.204 | 0.3478 | 1 | 0.027082 | 1.0885 | 0.22413 | 0.3 | 0.16421 | 0.25024 |
| 2.382 | 8.7572 | 1.682 | 0.70005 | 1 | 0.028885 | 1.4285 | 0.29389 | 0.4 | 0.16421 | 0.27514 |
| 4.5435 | 20.6432 | 2.8917 | 1.6518 | 1 | 0.030025 | 2.2722 | 0.36355 | 0.5 | 0.16421 | 0.31283 |

## B Country coverage and descriptive statistics

Table 4: Coverage of capital shares and top income shares in the original data (Bengtsson and Waldenström, 2018)

| Country (ISO) | Capital share gross of capital depreciation | Capital share net of capital depreciation | Top 10 % income share | Top 1 % income share | Top 0.1 % income share |
|---|---|---|---|---|---|
| ARG | 1913-2000 | no data | no data | 1932-1961 (3 NAs), 1970-1973, 1997-2004 | 1932-1961 (3 NAs), 1970-1973, 1997-2004 |
| AUS | 1911-2010 | 1911-2010 | 1941-2010 | 1921-2010 | 1921-2010 |
| AUT | 1924-1937, 1948-2010 | 1924-1937, 1948-2010 | no data | no data | no data |
| BEL | 1920-1939, 1960-2015 | 1920-1939, 1960-2015 | no data | no data | no data |
| BRA | 1920-2000 | | no data | no data | no data |
| CAN | 1926-2011 | 1926-2011 | 1941-2010 | 1920-2010 | 1920-2010 |
| DNK | 1876-2015 | 1876-2015 (NAs for 1915-1920) | 1903, 1908, 1915, 1917-1968, 1970-2010 | 1903, 1908, 1915, 1917-1968, 1970-2010 (1973 NA) | 1903, 1908, 1915, 1917-1966, 1971-2010 (2 NAs) |
| FIN | 1900-2015 | 1900-2015 | 1990-2009 | 1920-2009 | no data |
| FRA | 1900-2010 | 1900-2010 | 1900, 1910, 1915-2013 | 1900, 1910, 1915-2013 | 1900, 1910, 1915-2013 |

Table 4 continues

| Country (ISO) | Capital share gross of capital depreciation | Capital share net of capital depreciation | Top 10 % income share | Top 1 % income share | Top 0.1 % income share |
|---|---|---|---|---|---|
| DEU | 1891-1913, 1925-1938, 1950-2011 | 1891-1913, 1925-1938, 1950-2011 | 1891-1919, 1926, 1928, 1932, 1934, 1936, 1950, 1961, every third year for 1965-1998, 2001-2008 | 1891-1919, 1925-1938 (2 NAs), 1950, 1957, 1961, every third year for 1965-1998, 2001-2008 | 1891-1919, 1925-1938 (2 NAs), 1950, 1954, 1957, 1961, every third year for 1965-1998, 2001-2008 |
| IRL | 1938, 1944-2010 | 1938, 1944-2010 | 1938, 1943, 1975-2009 | 1938, 1943, 1975-2009 | 1922-1953, 1964-1990 (1974 NA) |
| JPN | 1906-1940, 1953-2010 | 1906-1940, 1953-2010 | 1947-2010 | 1886-2010 (1946 NA) | 1886-2010 (1946 NA) |
| NLD | 1923-1938, 1949-2010 | 1923-1938, 1949-2010 | 1914-1939, 1941, 1946, 1950, 1952, 1953, 1957-1959, 1962, 1964, 1966, 1967, 1970, 1973, 1975, 1977, 1981, 1985, 1989-2012 | 1914-1939, 1941, 1946, 1950, 1952, 1953, 1957-1959, 1962, 1964, 1966, 1967, 1970, 1973, 1975, 1977, 1981, 1985, 1989-2012 | 1914-1939, 1941, 1946, 1950, 1952, 1953, 1957-1959, 1970, 1973, 1975, 1977, 1981, 1985, 1989-1999 |
| NZL | 1939-2010 | 1939-2010 | 1924-1930, 1933, 1934, 1936,1940, 1945-2010 (1961 NA) | 1921-1930, 1933-1940, 1945-2010 (1961 NA) | 1921-1930, 1933-1940, 1945-1989 (2 NAs) |
| NOR | 1910-1939, 1946, 1949-2015 | 1910-1939, 1946, 1949-2015 | 1875, 1888, 1906, 1910, 1913, 1929 1948-2008 (1956 NA) | 1875, 1888, 1892-1903, 1906, 1910, 1913, 1929 1938, 1948-2008 (1956 NA) | 1875, 1895, 1896, 1898-1903, 1906, 1929 1938, 1948-2008 (1956 NA) |

Table 4 continues

| Country (ISO) | Capital share gross of capital depreciation | Capital share net of capital depreciation | Top 10 % income share | Top 1 % income share | Top 0.1 % income share |
|---|---|---|---|---|---|
| ESP | 1900-2000 | 1900-2000 | 1981-2012 | 1981-2012 | 1954, 1955, 1957-1959, 1961, 1971, 1981-2012 |
| SWE | 1875-2015 | 1875-2015 | 1903, 1907, 1911, 1912, 1916, 1919, 1920, 1930, 1934, 1935, 1941, 1943-2012 | 1903, 1907, 1911, 1912, 1916, 1919, 1920, 1930, 1934, 1935, 1941, 1943-2012 | 1903, 1907, 1911, 1912, 1916, 1919, 1920, 1930, 1934, 1935, 1941, 1943-2012 |
| GBR | 1891-2011 | 1891-2011 | 1918, 1919, 1937, 1949, 1954, 1959, 1962-1979, 1981-2007, 2009 | 1918, 1919, 1937, 1949, 1951-1979 (1961 NA), 1981-2007, 2009 | 1913-1986 (2 NAs), 1993-2007, 2009 |
| USA | 1929-2010 | 1929-2010 | 1917-2012 | 1913-2012 | 1913-2012 |

**Treatment of likely outliers.** Setting the focus on the five-year non-overlapping windows reduces the impact of potential outliers in the time series for the top income shares and capital shares substantially. However, four suspicious cases – which all are treated by taking average of the previous and the next observation corresponding to the five-year windows – remain:

- Denmark 1915: all top income measures and both capital share measures
- Finland 1950: both capital share measures
- France 1945: both capital share measures
- Norway 2005: all top income measures and both capital share measures

**The coverage of the estimation sample.** The coverage (230 observations in total, 13 countries, 13-21 growth windows per country) is reported in Table 5.

Table 5: Estimation sample

For a given year $t$, the growth of per capita GDP is the annualized growth rate from $t$ to $t+4$. The explanatory variables are averages over $t-5$ and $t-1$.

| Year | AUS | CAN | DNK | FIN | FRA | DEU | JPN | NLD | NZL | NOR | SWE | GBR | USA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1900 | | | | | | ✓ | | | | | | | |
| 1905 | | | | | ✓ | ✓ | | | | | | | |
| 1910 | | | ✓ | | ✓ | ✓ | | | | | ✓ | | |
| 1915 | | | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | | |
| 1920 | | | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | | |
| 1925 | | | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | |
| 1930 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | |
| 1935 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ |
| 1940 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ |
| 1945 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| 1950 | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | ✓ |
| 1955 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 1960 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 1965 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 1970 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 1975 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 1980 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 1985 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 1990 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 1995 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2000 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2005 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2010 | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ |

Table 6: Descriptive statistics, five-year intervals

| Variable | Mean | Std. dev. | Min | Max | Obs |
|---|---|---|---|---|---|
| Full sample, 1900–2010, see Table 5 in Appendix B for details | | | | | |
| Growth of per capita GDP | 2.02 % | 2.72 % | -18.93 % | 12.81 % | 230 |
| Top 1 % income share | 10.44 % | 4.48 % | 4.03 % | 26.25 % | 230 |
| Capital share | 26.10 % | 6.70 % | 11.91 % | 44.25 % | 230 |
| 1900–1945 | | | | | |
| Growth of per capita GDP | 1.62 % | 4.43 % | -18.93 % | 12.81 % | 67 |
| Top 1 % income share | 15.75 % | 3.63 % | 7.42 % | 26.25 % | 67 |
| Capital share | 31.58 % | 6.22 % | 16.07 % | 44.25 % | 67 |
| 1950–1980 | | | | | |
| Growth of per capita GDP | 2.84 % | 1.53 % | 0.37 % | 8.68 % | 88 |
| Top 1 % income share | 8.61 % | 1.95 % | 5.13 % | 14.13 % | 88 |
| Capital share | 24.12 % | 5.73 % | 12.25 % | 36.92 % | 88 |
| 1985–2010 | | | | | |
| Growth of per capita GDP | 1.42 % | 1.15 % | -0.95 % | 4.50 % | 75 |
| Top 1 % income share | 7.84 % | 3.11 % | 4.03 % | 17.68 % | 75 |
| Capital share | 23.52 % | 5.21 % | 11.91 % | 33.51 % | 75 |

Notes: The growth of per capita GDP correspond to annualized growth rate inside five-year windows while the top income share and capital share are averages over the five-year intervals preceding the growth windows and measure the share of total national income in percentages.

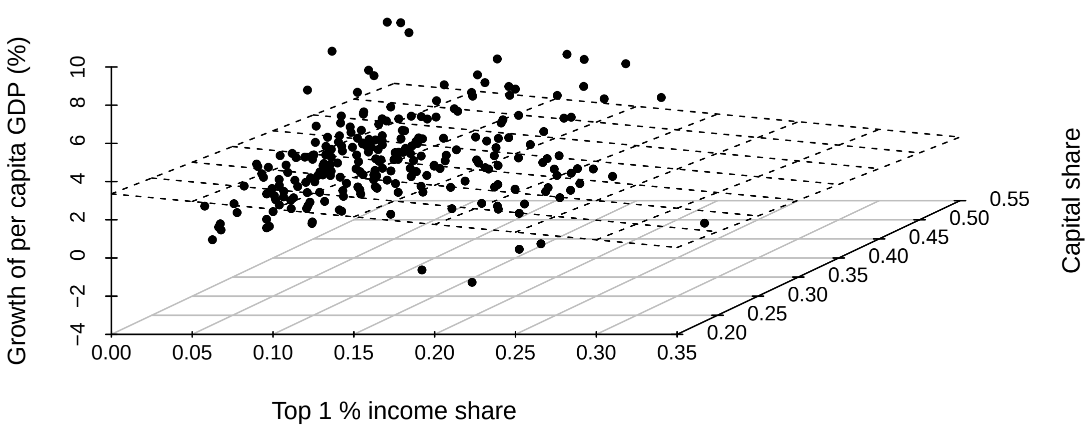



Figure 8: Pooled least squares regression plane: five-year non-overlapping windows, contemporaneous timing

# C Alternative empirical specifications

**Potential dependency to the level of inequality rather than to capital share**

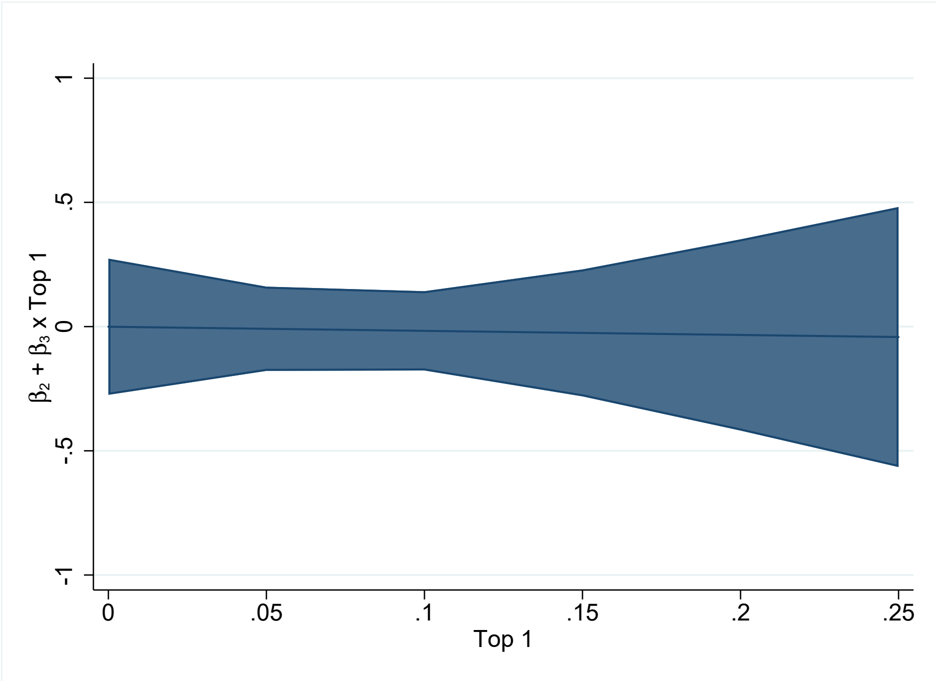
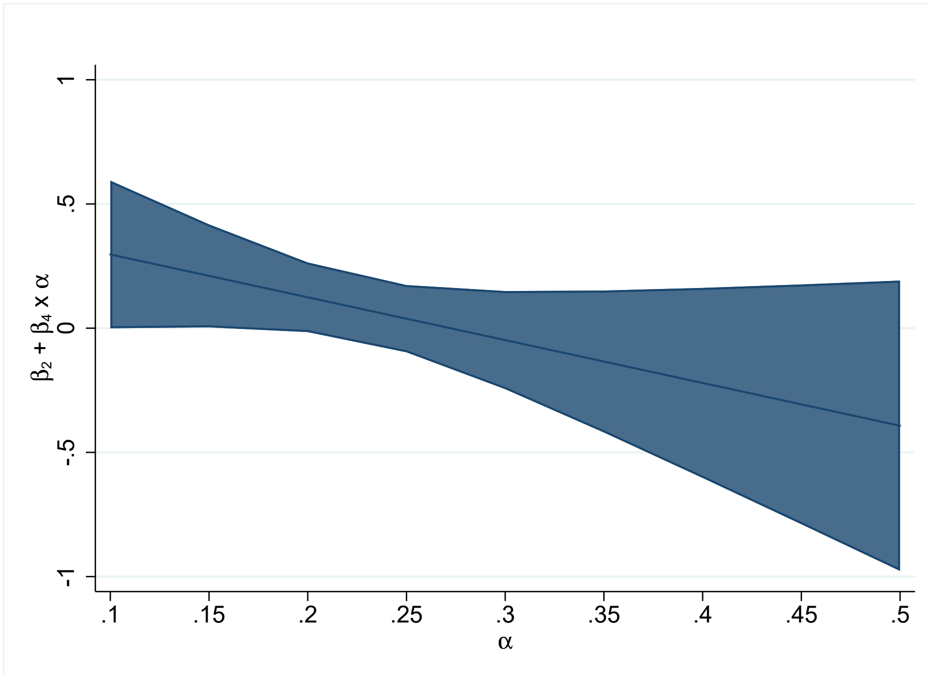
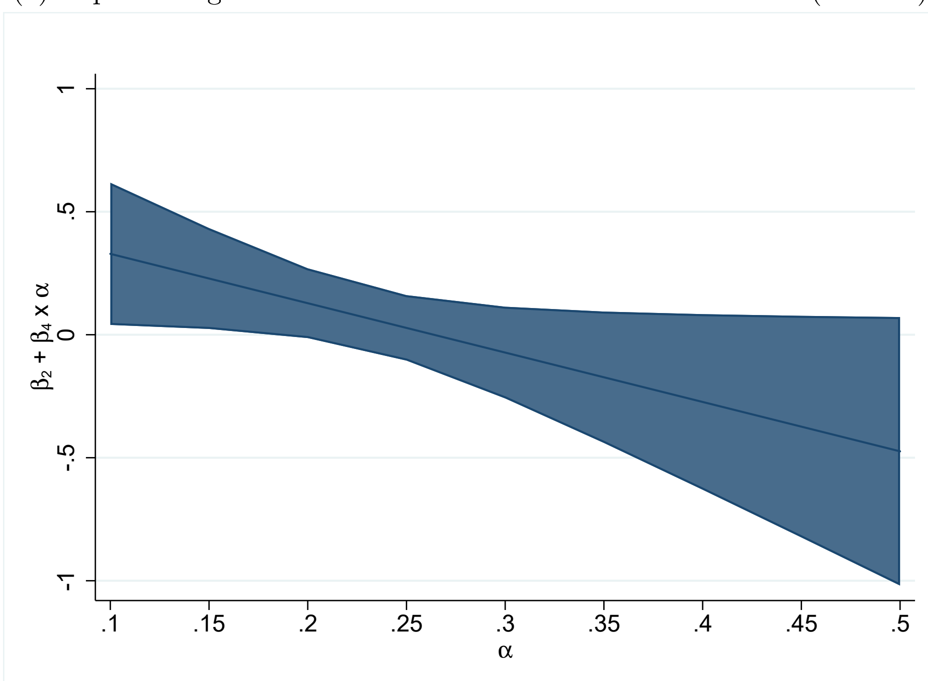



Figure 9: The association between growth of per capita GDP and top 1 % income share conditional on top1 % income share (point estimate and 95 % confidence interval), $\beta_2$ and $\beta_3$ correspond to equation (15)

**The inclusion of additional variables as controls**

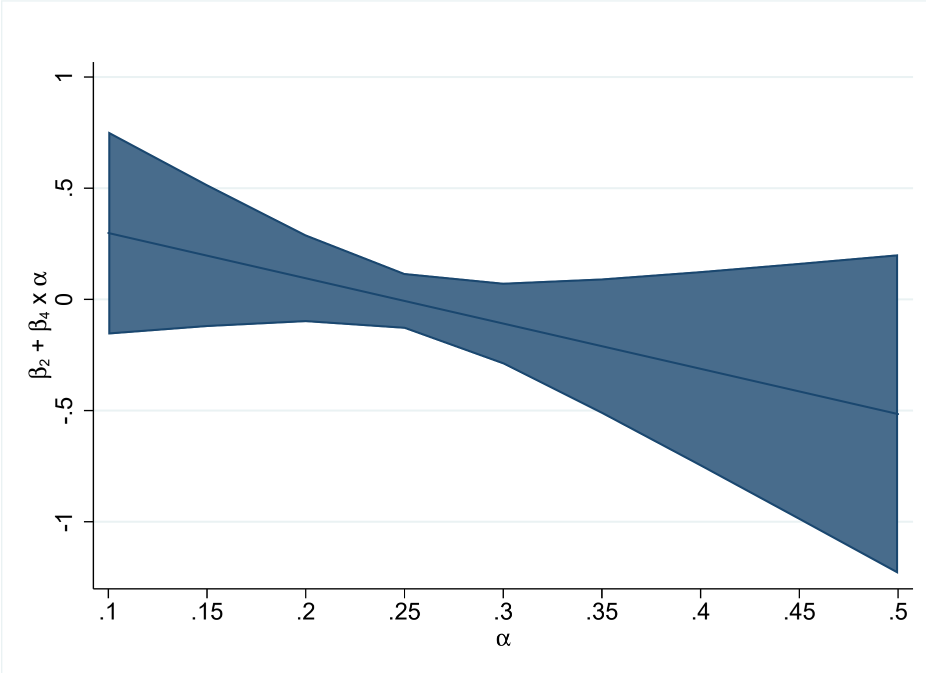



(a) Population growth and educational attainment as controls (230 obs)




(b) Population growth, educational attainment and investment per GDP as controls (212 obs)

Figure 10: The association between growth of per capita GDP and top 1 % income share conditional on capital share (point estimate and 95 % confidence interval)

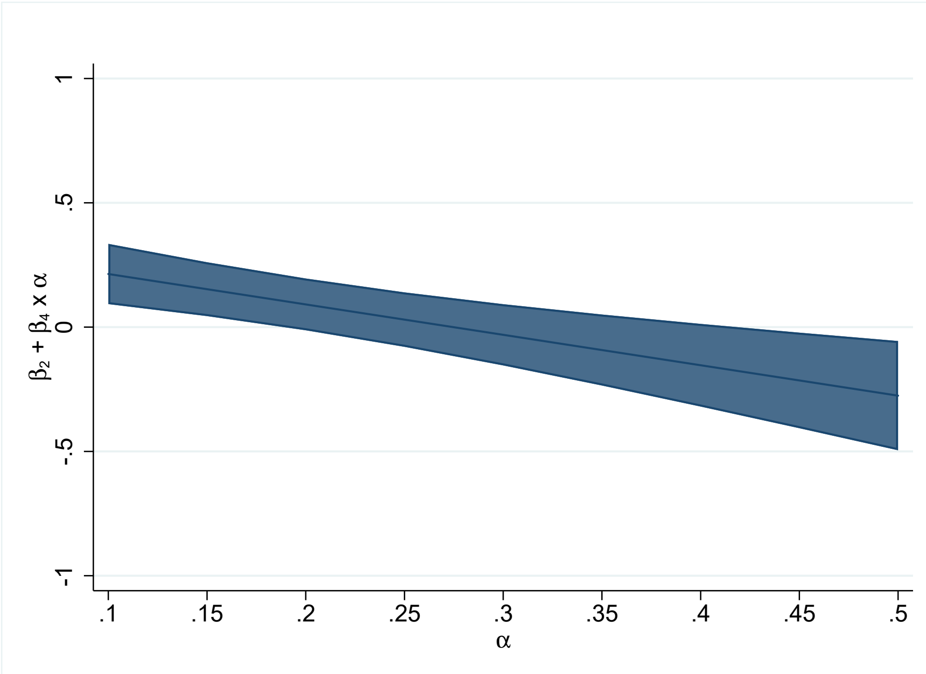



(c) Population growth, educational attainment, investment per GDP, public debt per GDP and the sum of exports and imports per GDP as controls (199 obs)

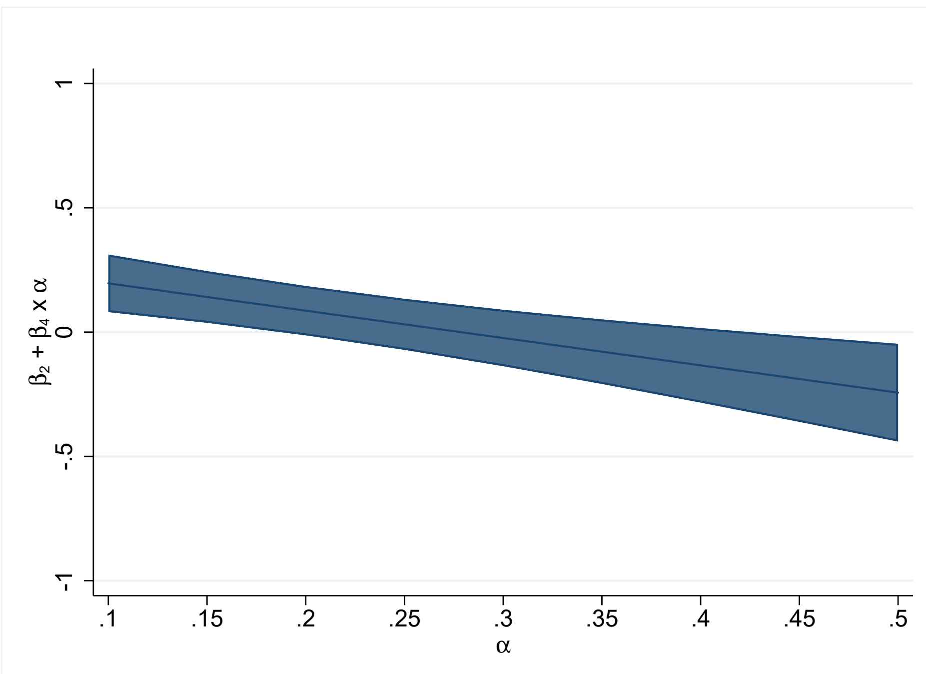
Figure 10: The association between growth of per capita GDP and top 1 % income share conditional on capital share (point estimate and 95 % confidence interval)

*Notes:* $\beta_2$ and $\beta_4$ correspond to equation (14) with the additional control variables listed in the captions.

**Excluding the extreme growth rates of per capita GDP**



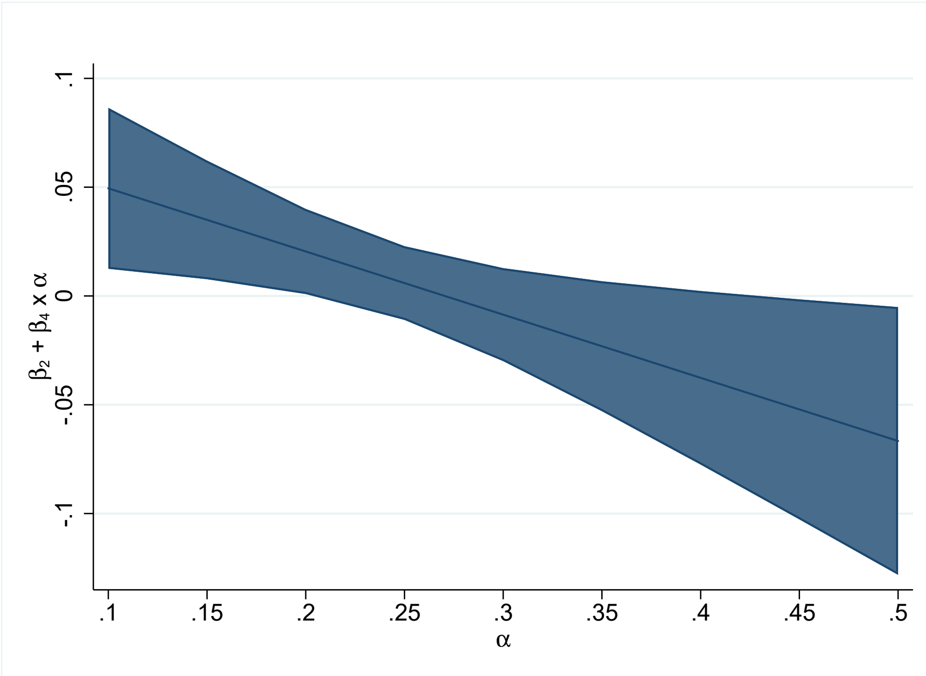

(a) Excluding the highest and lowest 5 % of the growth rates of per capita GDP



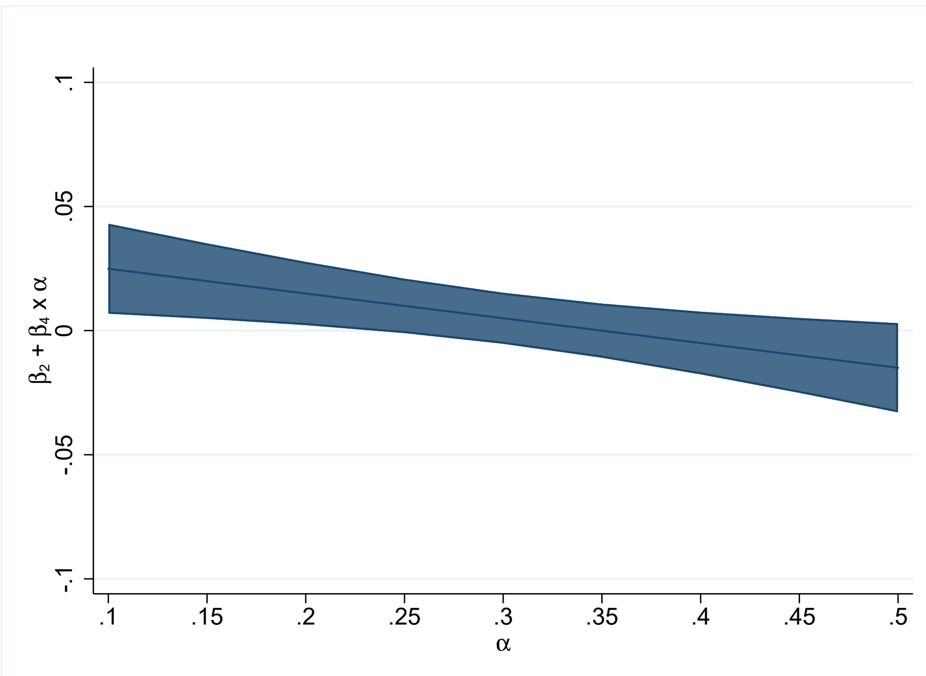

(b) Excluding the highest and lowest 10 % of the growth rates of per capita GDP

Figure 11: The association between growth of per capita GDP and top 1 % income share conditional on capital share and on top 1 % income share (point estimate and 95 % confidence interval), $\beta_2$ and $\beta_4$ correspond to equation (14) but lowest and highest growth rates of per capita GDP are excluded from the estimation sample

**Top 10 % and top 0.1 %**

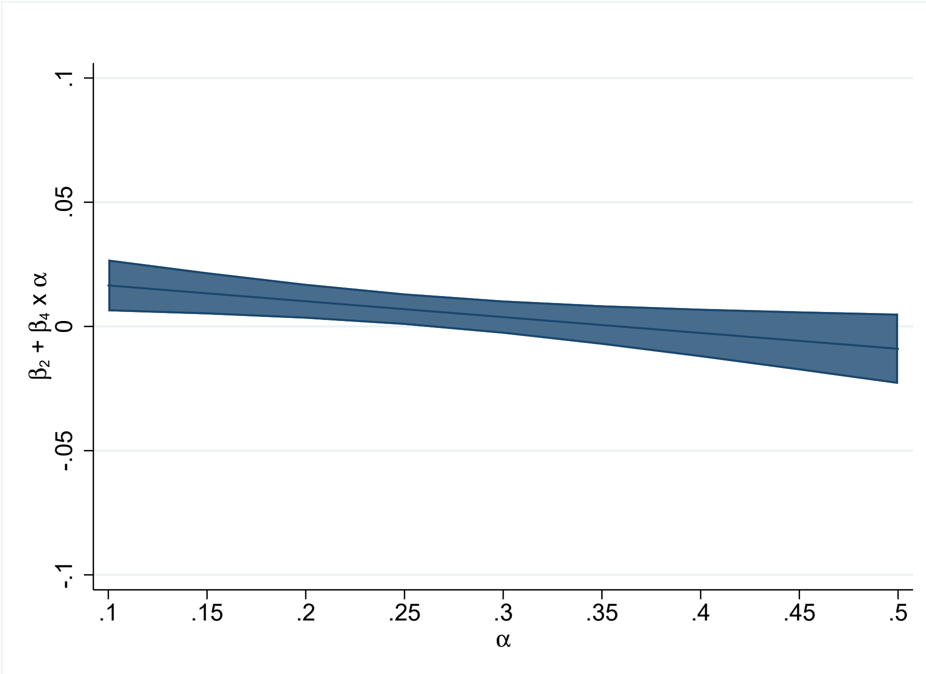



(a) Top 10 % share




(b) Top 1 % share

Figure 12: The association between growth of per capita GDP and different top income shares conditional on capital share (point estimate and 95 % confidence interval)

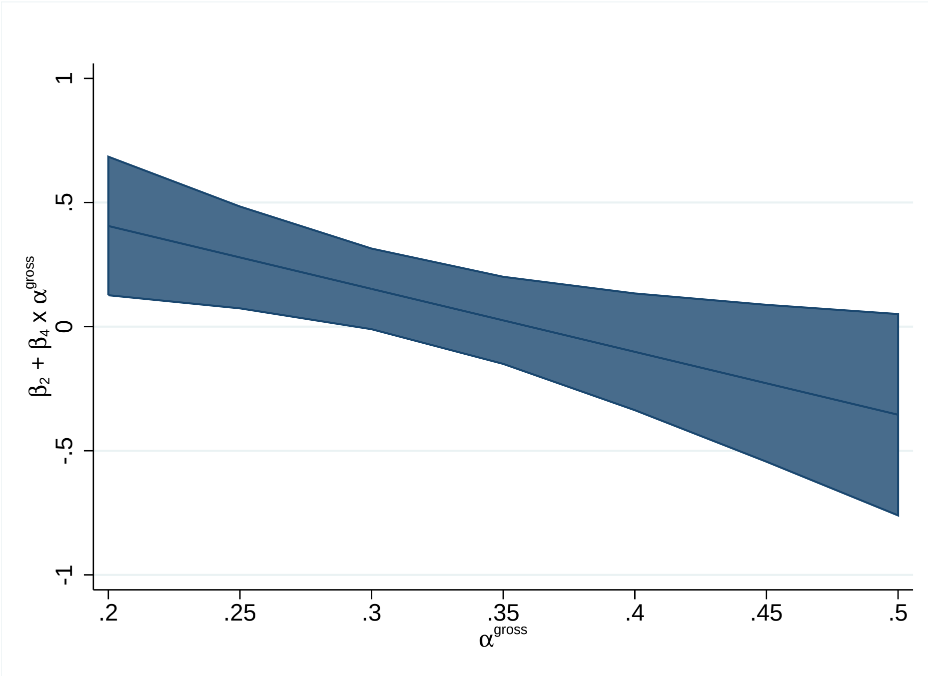



(c) Top 0.1 % share

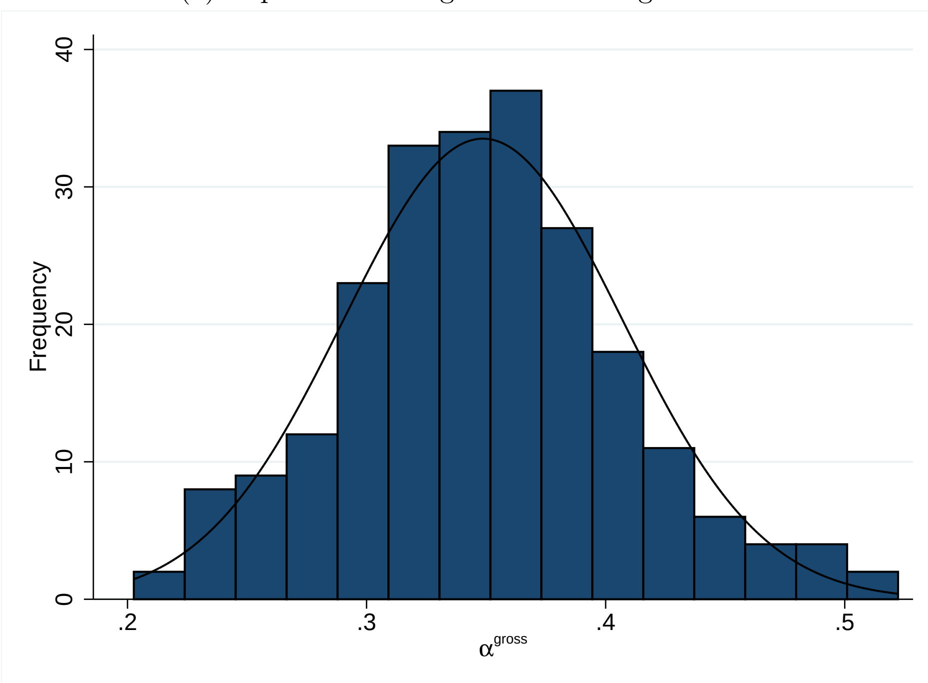
Figure 12: The association between growth of per capita GDP and different top income shares conditional on capital share (point estimate and 95 % confidence interval)

*Notes:* $\beta_2$ and $\beta_4$ correspond to equation (14) with top 1 % share in logs in Figure 12b, and to equation (14) with top 10 % and top 0.1 % share in logs in Figures 12a and 12c, respectively.

**Capital shares gross of capital depreciation**



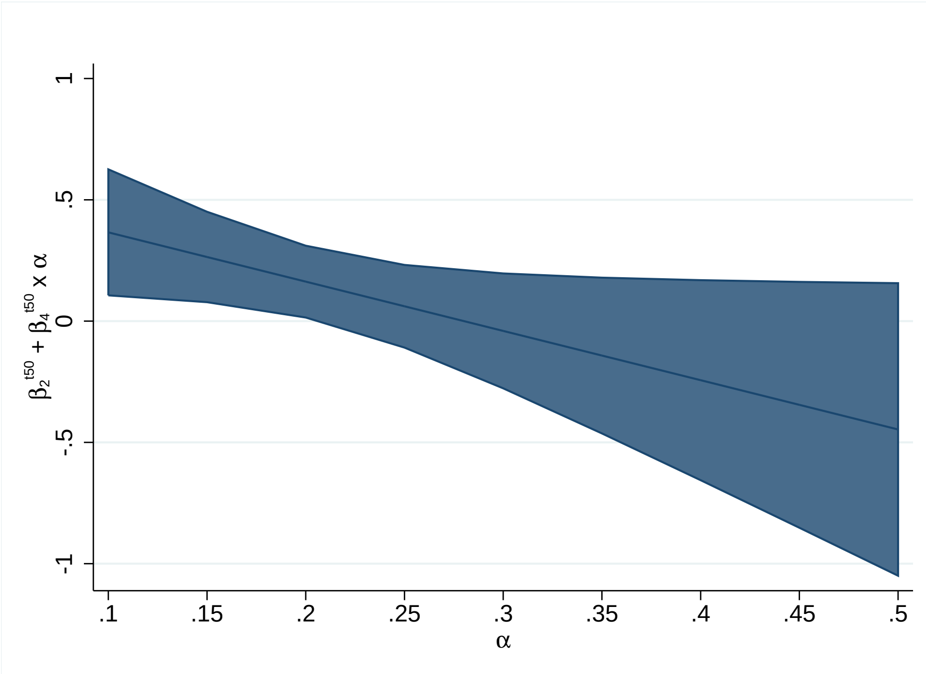

(a) Replication of Figure 6a with $\alpha$ gross of $\delta$



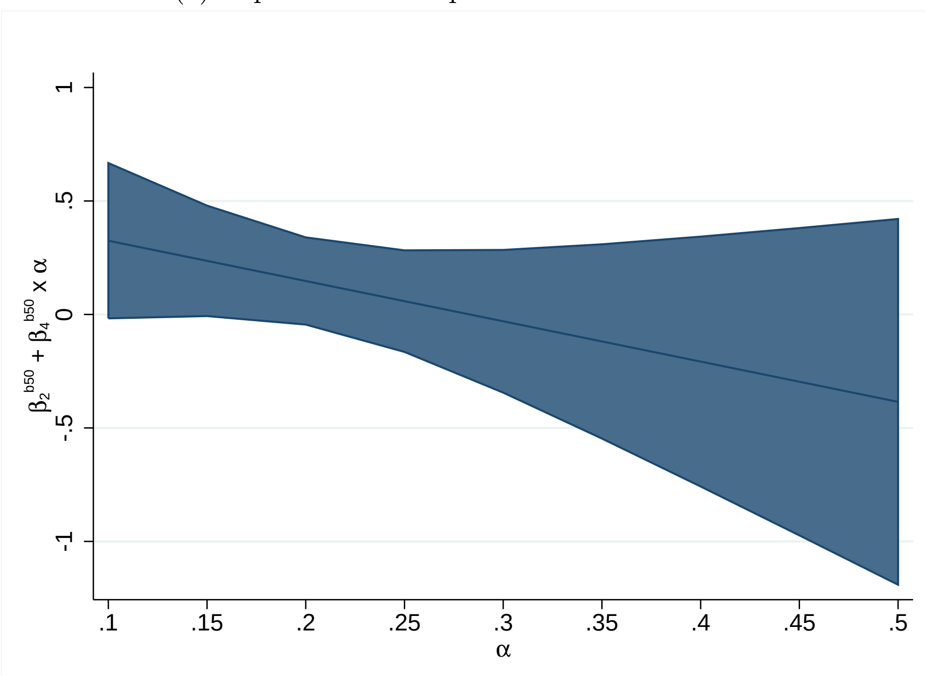

(b) Distribution of capital share gross of $\delta$ in the estimation sample

Figure 13: The association between growth of per capita GDP and top 1 % income share conditional on capital share ($\alpha$) gross of capital depreciation ($\delta$) (point estimate and 95 % confidence interval), $\beta_2$ and $\beta_4$ correspond to equation (14)

**Addressing dependency to both the extent of inequality and capital share**




(a) Top 1 % at the top half of the distribution




(b) Top 1 % at the bottom half of the distribution

Figure 14: The association between growth of per capita GDP and top 1 % income share conditional on capital share and on top 1 % income share (point estimate and 95 % confidence interval), $\beta_2$ and $\beta_4$ correspond to equation (16)

**Average annual growth instead of annualized growth**

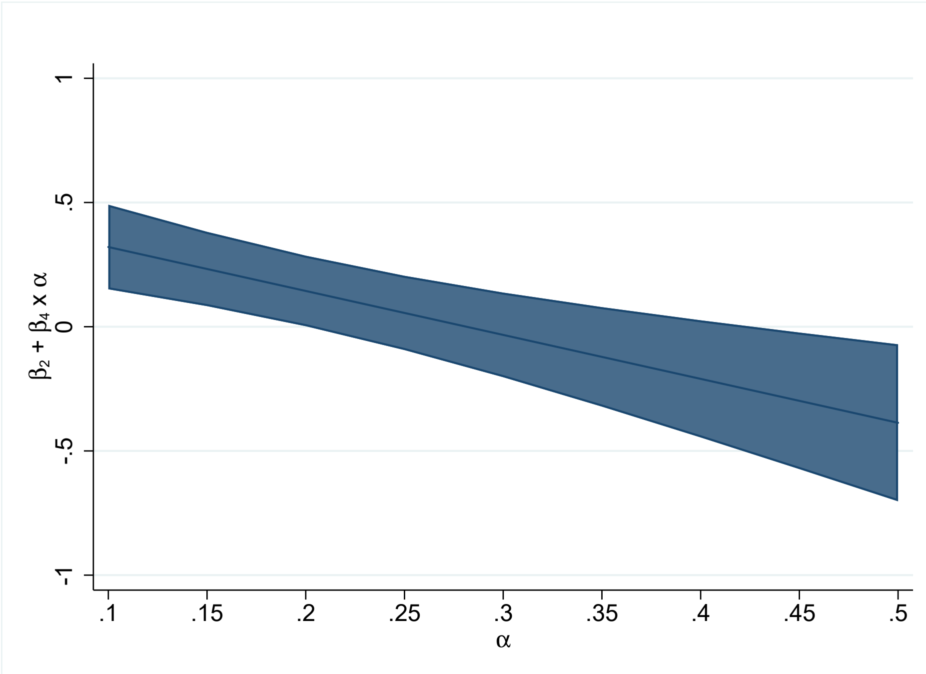
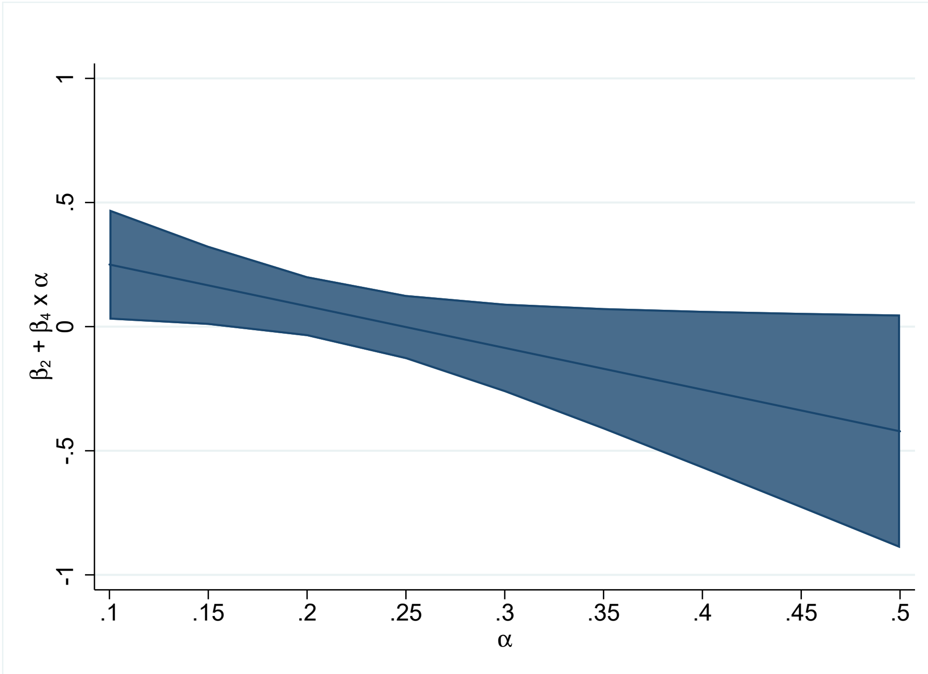
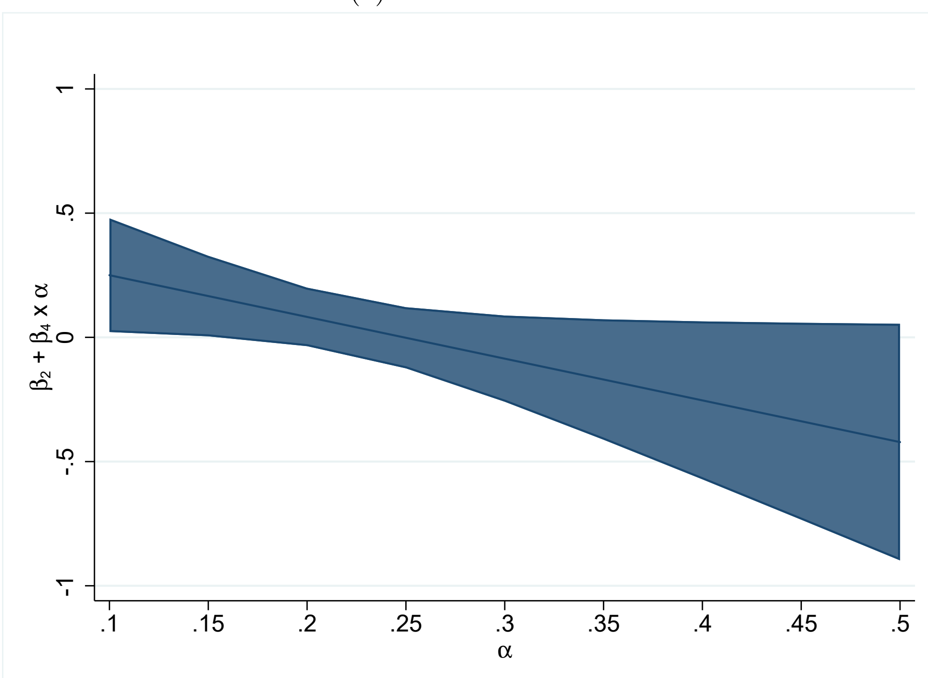



Figure 15: The association between growth of per capita GDP and top 1 % income share conditional on capital share (point estimate and 95 % confidence interval), average annual growth rates inside five-year windows

**Different panel estimators**




(a) Random effects




(b) Pooled OLS

Figure 16: The association between growth of per capita GDP and top 1 % income share conditional on capital share (point estimate and 95 % confidence interval), alternative panel estimators

# D Measures of financial development over the twentieth century

Table 7: Data from Rajan and Zingales (2003)

No data for Finland and New Zealand. The original paper also includes Argentina, Austria, Belgium, Brazil, Chile, Cuba, Egypt, India, Italy, Russia, South Africa, Spain and Switzerland

Panel A: Commercial and savings deposits to GDP

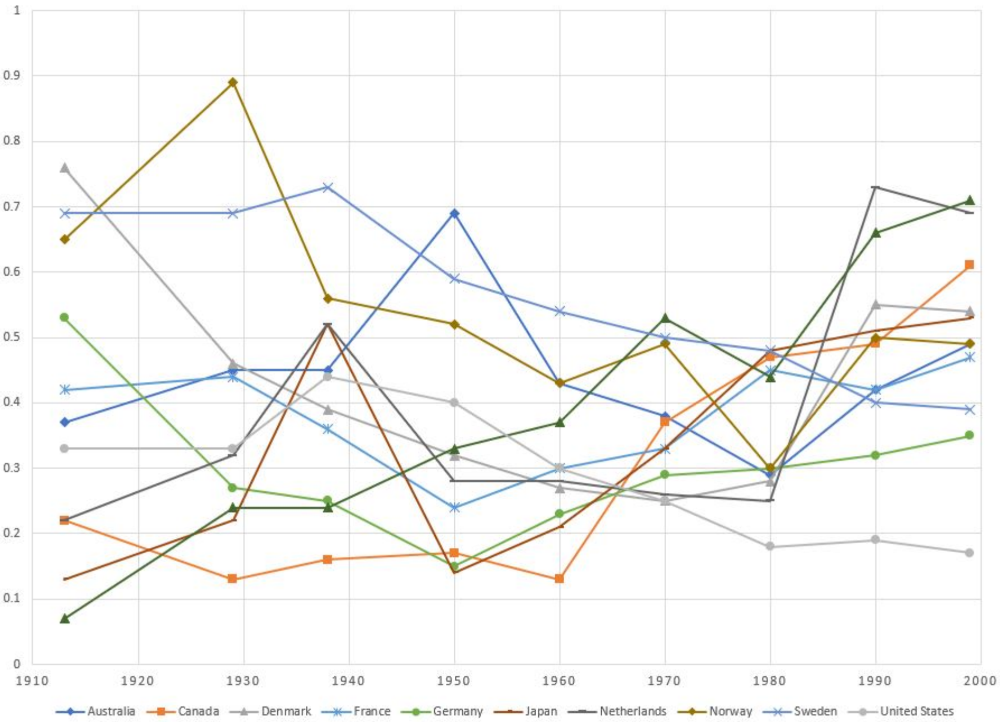
| Country | 1913 | 1929 | 1938 | 1950 | 1960 | 1970 | 1980 | 1990 | 1999 |
|---|---|---|---|---|---|---|---|---|---|
| Australia | 0.37 | 0.45 | 0.45 | 0.69 | 0.43 | 0.38 | 0.29 | 0.42 | 0.49 |
| Canada | 0.22 | 0.13 | 0.16 | 0.17 | 0.13 | 0.37 | 0.47 | 0.49 | 0.61 |
| Denmark | 0.76 | 0.46 | 0.39 | 0.32 | 0.27 | 0.25 | 0.28 | 0.55 | 0.54 |
| France | 0.42 | 0.44 | 0.36 | 0.24 | 0.3 | 0.33 | 0.45 | 0.42 | 0.47 |
| Germany | 0.53 | 0.27 | 0.25 | 0.15 | 0.23 | 0.29 | 0.3 | 0.32 | 0.35 |
| Japan | 0.13 | 0.22 | 0.52 | 0.14 | 0.21 | 0.33 | 0.48 | 0.51 | 0.53 |
| Netherlands | 0.22 | 0.32 | 0.52 | 0.28 | 0.28 | 0.26 | 0.25 | 0.73 | 0.69 |
| Norway | 0.65 | 0.89 | 0.56 | 0.52 | 0.43 | 0.49 | 0.3 | 0.5 | 0.49 |
| Sweden | 0.69 | 0.69 | 0.73 | 0.59 | 0.54 | 0.5 | 0.48 | 0.4 | 0.39 |
| United Kingdom | 0.1 | 2.88 | 1.34 | 0.67 | 0.32 | 0.22 | 0.14 | 0.33 | 0.39 |
| United States | 0.33 | 0.33 | 0.44 | 0.4 | 0.3 | 0.25 | 0.18 | 0.19 | 0.17 |

Panel B: Stock market capitalization (aggregate market value of equity of domestic companies) to GDP

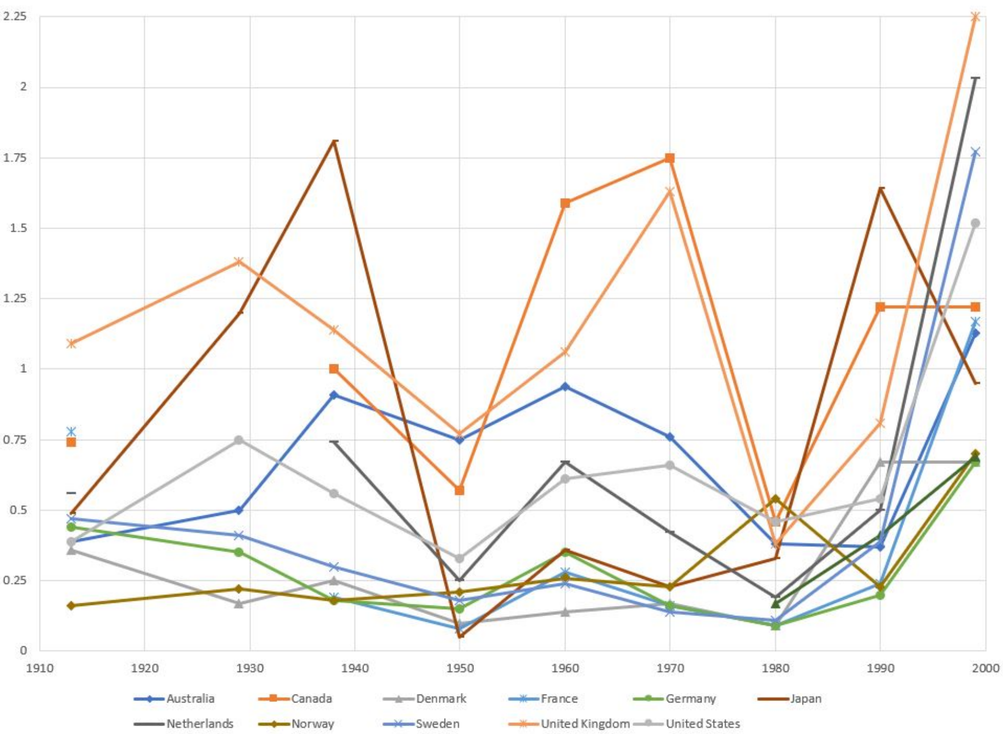
| Country | 1913 | 1929 | 1938 | 1950 | 1960 | 1970 | 1980 | 1990 | 1999 |
|---|---|---|---|---|---|---|---|---|---|
| Australia | 0.39 | 0.5 | 0.91 | 0.75 | 0.94 | 0.76 | 0.38 | 0.37 | 1.13 |
| Canada | 0.74 | | 1 | 0.57 | 1.59 | 1.75 | 0.46 | 1.22 | 1.22 |
| Denmark | 0.36 | 0.17 | 0.25 | 0.1 | 0.14 | 0.17 | 0.09 | 0.67 | 0.67 |
| France | 0.78 | | 0.19 | 0.08 | 0.28 | 0.16 | 0.09 | 0.24 | 1.17 |
| Germany | 0.44 | 0.35 | 0.18 | 0.15 | 0.35 | 0.16 | 0.09 | 0.2 | 0.67 |
| Japan | 0.49 | 1.2 | 1.81 | 0.05 | 0.36 | 0.23 | 0.33 | 1.64 | 0.95 |
| Netherlands | 0.56 | | 0.74 | 0.25 | 0.67 | 0.42 | 0.19 | 0.5 | 2.03 |
| Norway | 0.16 | 0.22 | 0.18 | 0.21 | 0.26 | 0.23 | 0.54 | 0.23 | 0.7 |
| Sweden | 0.47 | 0.41 | 0.3 | 0.18 | 0.24 | 0.14 | 0.11 | 0.39 | 1.77 |
| United Kingdom | 1.09 | 1.38 | 1.14 | 0.77 | 1.06 | 1.63 | 0.38 | 0.81 | 2.25 |
| United States | 0.39 | 0.75 | 0.56 | 0.33 | 0.61 | 0.66 | 0.46 | 0.54 | 1.52 |

| Panel C: Amount of funds raised through public equity offerings (both initial public offerings and seasoned equity issues) by domestic companies divided by gross fixed capital formation | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Country | 1913 | 1929 | 1938 | 1950 | 1960 | 1970 | 1980 | 1990 | 1999 |
| Australia | | 0.13 | | 0.19 | 0.09 | 0.05 | 0.05 | 0.09 | 0.24 |
| Canada | | | 0.02 | 0.03 | 0.03 | 0.01 | 0.04 | 0.01 | 0.07 |
| Denmark | | 0.03 | 0.01 | | | | 0.01 | 0.08 | 0.09 |
| France | 0.14 | 0.26 | 0.03 | 0.02 | 0.04 | 0.04 | 0.06 | 0.02 | 0.09 |
| Germany | 0.07 | 0.17 | 0.06 | 0 | 0.04 | 0.02 | 0.01 | 0.04 | 0.06 |
| Japan | 0.08 | 0.13 | 0.75 | | 0.15 | 0.03 | 0.01 | 0.02 | 0.08 |
| Netherlands | 0.38 | 0.61 | 0.45 | 0.02 | 0.02 | 0 | 0.01 | 0.1 | 0.67 |
| Norway | | 0.05 | 0.01 | | | | | 0.04 | 0.06 |
| Sweden | 0.08 | 0.34 | 0.06 | 0.01 | 0.03 | 0 | 0 | 0.03 | 0.1 |
| United Kingdom | 0.14 | 0.35 | 0.09 | 0.08 | 0.09 | 0.01 | 0.04 | 0.06 | 0.09 |
| United States | 0.04 | 0.38 | 0.01 | 0.04 | 0.02 | 0.07 | 0.04 | 0.04 | 0.12 |

| Panel D: The number of domestic companies whose equity is publicly traded in a domestic stock exchange divided by the population in millions | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Country | 1913 | 1929 | 1938 | 1950 | 1960 | 1970 | 1980 | 1990 | 1999 |
| Australia | 61.74 | 76.92 | 84.88 | 122.05 | 93.72 | | 68.53 | 63.89 | 64.91 |
| Canada | 14.65 | | | 66.61 | 62.43 | 55.2 | 50.52 | 42.99 | 130.13 |
| Denmark | 38.22 | 54.86 | 85.25 | 81.28 | 75.75 | 52.14 | 42.54 | 50.18 | 44.8 |
| France | 13.29 | | 24.64 | 26.2 | 18.34 | 15.98 | 13.99 | 15.05 | |
| Germany | 27.96 | 19.73 | 10.91 | 13.22 | 11.33 | 9.07 | 7.46 | 6.53 | 12.74 |
| Japan | 7.53 | 16.65 | 19.48 | 9.15 | 8.35 | 15.19 | 14.8 | 16.76 | 20 |
| Netherlands | 65.87 | 95.48 | | | 21.42 | 15.95 | 15.12 | 17.39 | 15.14 |
| Norway | 33.51 | 41.5 | 45.98 | 37.98 | 37.1 | 37.9 | 44.53 | 44.8 | 49.62 |
| Sweden | 20.64 | 16.36 | 14.93 | 12.83 | 14.04 | 13.18 | 12.39 | 14.14 | 31.46 |
| United Kingdom | 47.06 | | | | | | 47.22 | 29.63 | 31.11 |
| United States | 4.75 | 9.72 | 9.16 | 8.94 | 9.33 | 11.48 | 23.11 | 26.41 | 28.88 |

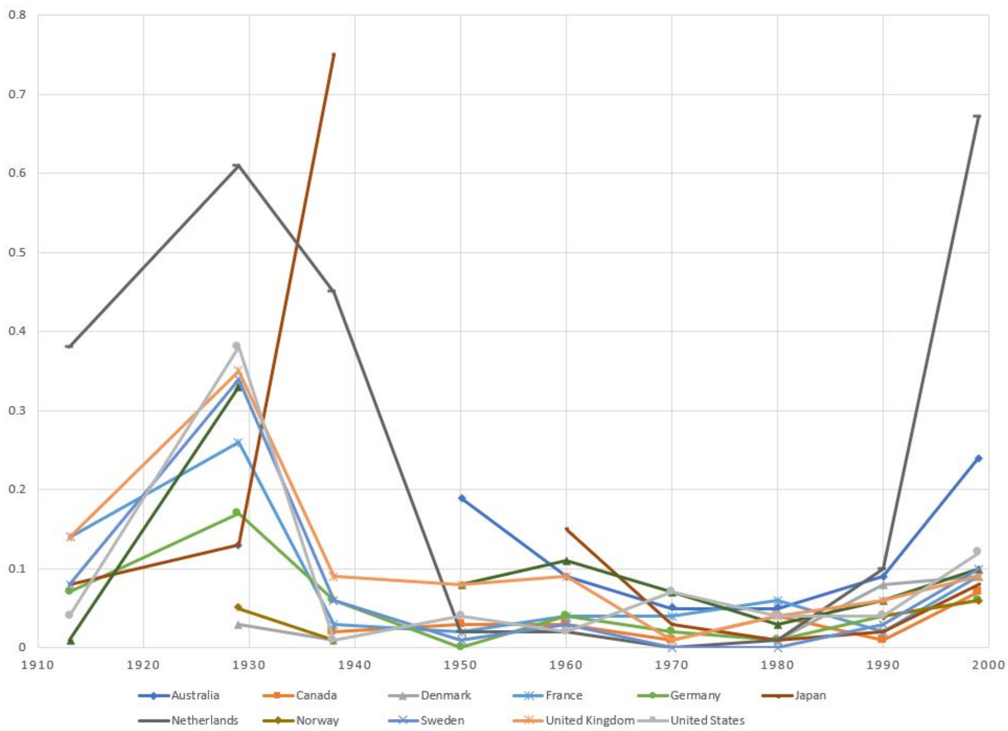



(a) Commercial and savings deposits to GDP

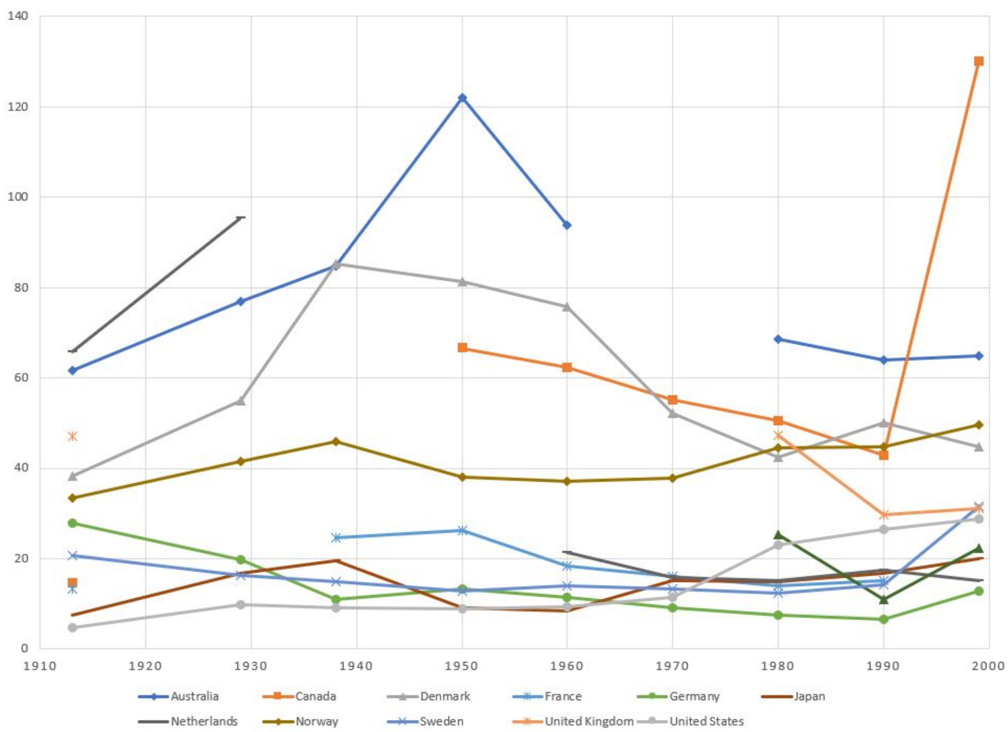



(b) Stock market capitalization (aggregate market value of equity of domestic companies) to GDP

Figure 17: Data from Rajan and Zingales (2003)




(c) Amount of funds raised through public equity offerings (both initial public offerings and seasoned equity issues) by domestic companies divided by gross fixed capital formation




(d) The number of domestic companies whose equity is publicly traded in a domestic stock exchange divided by the population in millions

Figure 17: Data from Rajan and Zingales (2003)